



**DESIGN SPECIFICATIONS for
VAPOR EXTRACTION SYSTEMS**

at

**V.I.P. DRY CLEANERS
89 Morris Street
Morristown, New Jersey**

Prepared for:

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May 3, 2007

89 Morris Street Property, Morristown, NJ Phase II

1.0 GENERAL INFORMATION

- 1.1** An investigation authorized by the Comprehensive Environmental Response, Compensation Act, 42 U.S.C. 9601 (CERCLA or the Superfund Law) has determined that the property at 89 Morris Street has been impacted by the intrusion of VOC vapors emanating from ground water and soil contamination related to the former VIP Cleaners. The indoor air contains elevated concentrations of tetrachloroethylene (PCE). There have also been higher concentrations of PCE identified beneath the concrete slabs. These concentrations exceed the acceptable health based concentrations.

EPA has determined that corrective action is required to mitigate the health based threats within the rental spaces. The information in this report fulfills EPA's required scope of work and work plan for the purpose of implementing remedial action.

- 1.2** The building at 89 Morris Street is a complex structure consisting of joined buildings and multiple additions. The portion of the building that faces Morris Street has housed several Dry Cleaning Operations from 1945 to the present. The back portion and laundry area of the present Dry Cleaner was the original Dry Cleaner building that was built in 1945. The store front that faces Morris Street, which is the clothing pick up and drop off area was added in 1950. In 1952, a single structure consisting of five retail stores was added to the back of the original Dry Cleaner. Approximately thirty feet away from the five retail units is a stand alone store building that was built in 1942. In 1960, walls and a roof were constructed; and a slab poured connecting the five retail unit structure with the stand alone 1942 building. At some point during this time period a ten by eighty-five foot addition was built on the East side of the original Dry Cleaner eliminating the side alley way. In 1998, there was a fifteen foot addition put across the front of the five unit structure and the section that joins the five unit structure to the 1942 building.

Designing an effective Soil Ventilation System requires understanding the relationship between the impacted soil and all of the building segments. Since the present Dry Cleaner will be vacating the leased space sometime between November 1, 2006 and December, 31, 2006 a decision has been made to conduct the diagnostic procedures on this portion of the building after the space has been vacated. On September 6th and 7th sub slab soil classification and permeability mapping was conducted on the remaining three quarters of the building. A report of those findings was delivered on September 19, 2006. The remedial actions recommended in that document were implemented October 5, 2006 through October 21, 2006. An interim project report on installation activities was presented on January 4, 2007.

- 1.3** The focus of this diagnostic report and work plan is Rental Area 10, the VIP Dry Cleaner itself. This is the portion of the building that faces Morris Street and has housed several Dry Cleaning Operations from 1945 to the present. The back portion and laundry area of the present Dry Cleaner was the original Dry Cleaner building that was built in 1945. The store front that faces Morris Street, which is the clothing pick up and drop off area was added in 1950. There are also three small additions that were added during the 1950's and 1960's. All total the Dry Cleaner portion of the building is constructed of seven different foundation areas.

89 Morris Street Property, Morristown, NJ Phase II

2.0 PRINCIPLES OF CONTAMINANT ENTRY

There are three prerequisites for soil borne contaminant entry into a building. They are a nearby source, a driving force that transports contaminants through pathways into buildings, and the entry routes themselves. It is very difficult to stop the movement of contaminants by sealing openings. Soil contaminants predominantly enter a building because of pressure differences between the soil and the area above the slab. It is typically expected that contaminant levels will be higher during the heating season because the rising warm air, which escapes out the top of the building, causes the space directly over the slab to be negative in pressure compared to the soil. In addition, windows and doors are less likely to be left open during the heating season.

2.1 Temperature Driven Transport

When it is colder outside than inside, the warmer inside air is lighter; it rises and escapes the building through openings around upper windows and roof flanges. Similar to a hot air balloon, the large volume of air that is forcing its way upward is pulling on the floor below just like the balloon pulls on the basket. This force makes the building behave like a chimney. Temperature driven airflow is often referred to as stack effect. The resulting suction is applied to the floor by the rising warm air draws soil gases from beneath the building through pathways and into the occupied space.

2.2 Wind Driven Transport

Soil pollutants enters buildings when wind induced negative pressures are transferred into the structure resulting in the uptake of soil gas. Wind creates a complex pressure field around a building. It can create a positive pressure on the windward side and a negative pressure on the leeward side. When wind driven air travels over and around a building it has to travel a greater distance than the air that is blowing past the building in a parking lot or field. Similar to when air passes over an airplane wing, the air has to travel a longer distance around the top of the wing than the bottom. The resulting negative pressure or vacuum on the top side of the wing pulls the entire weight of the airplane up. Since the geometry of a strip mall building is not similar to an airplane wing, rarely is the roof pulled off a building, the vacuum created on the top and leeward side of the structure is strong enough to draw soil borne pollutants into the building.

2.3 Mechanically Driven Transport

Air moves through soils from areas of higher to lower air pressure. When air is mechanically drawn out of a building, air pressure differentials are created between inside and outside the building. The resulting negative pressure pulls air into the building to replace the air that has left. When the building is depressurized this way, air from the soil beneath the slab enters the building through

89 Morris Street Property, Morristown, NJ Phase II

cracks and other pathways and creates suction on the surrounding soil. Sometimes, contaminants enter the building because exhaust fans, such as the ones used in the Dry Cleaning operation, induce a negative pressure that pulls contaminants into the building. In other cases the HVAC creates a negative pressure where there are openings to the soil and it draws contaminants directly into the building. All of these entry mechanisms need to be considered when designing an Active Soil Depressurization system.

3.0 MITIGATION APPROACHES

- 3.1 The primary method for reducing soil borne pollutants is Active Soil Depressurization (ASD). ASD systems prevent soil borne pollutants entry into a building by creating a negative pressure beneath the slab. An ASD system will draw pollutants from beneath the slab, through PVC piping to the exterior of the building where it is vented above the roofline and quickly diluted with ambient air. The ASD system also removes moisture and other soil bourn pollutants that can enter the building and, therefore, improves the overall indoor air quality of the building.

4.0 CONSTRUCTION FEATURES

- 4.1 As referenced in Section 1.2, the building is made up of a series of additions and joined structures. The overall construction is slab on grade with stem walls. The underlying fill material beneath each of the building segments is native clay soil with the exception of where there is crushed stone beneath the 1998 addition. The roof construction is a flat roof with torch down rubber roofing material. The roof of the two story addition on the Northeast corner is roll asphalt material. Each segmented unit has its own roof mounted air handling unit.
- 4.2 Rental Area 10, the VIP Dry Cleaner itself is the focus of this investigation. This is the portion of the building that faces Morris Street and has housed several Dry Cleaning Operations from 1945 to the present. The back portion and laundry area of the present Dry Cleaner was the original Dry Cleaner building that was built in 1945. The store front that faces Morris Street, which is the clothing pick up and drop off area was added in 1950. There are also three small additions that were added during the 1950's and 1960's. All total the Dry Cleaner portion of the building is constructed of seven different foundation areas. The areas are listed on the table below.

Rental Area 10 Foundations

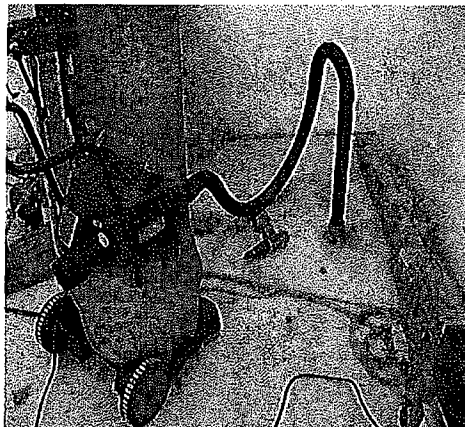
| Area | Description | Sub Slab Material |
|------|-----------------------------|-------------------------------|
| 10.1 | Office | Low permeable indigenous soil |
| 10.2 | Fitting Room | Indigenous loamy soil |
| 10.3 | Drop Off Area | Indigenous loamy soil |
| 10.4 | Central Overhead Rack Room | Thin cynder layer over clay |
| 10.5 | Hanging Laundry Boiler Room | Crushed stone |
| 10.6 | Raised Floor Laundry | Settled native soil |
| 10.7 | Dry Cleaning Room | Fine sand |

89 Morris Street Property, Morristown, NJ Phase II

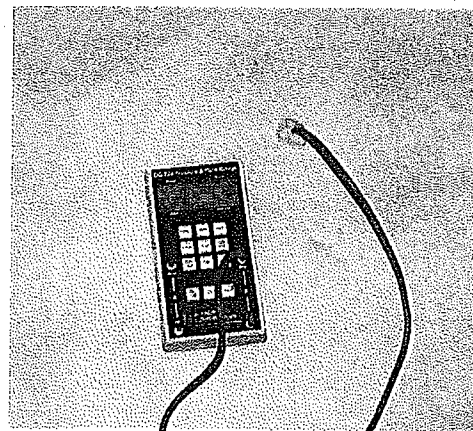
5.0 DIAGNOSTIC FINDINGS

5.1 Sub-Slab Pressure Field Tests

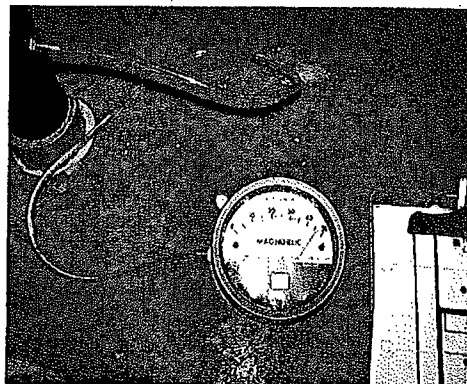
In order to determine the requirements of depressurizing the soil, sub-slab soil permeability testing was conducted on April 26, 2007. These tests required drilling holes through the concrete slabs at locations that would be practical to install a future contaminant depressurization pipe. A shop vacuum was used to draw air from the suction holes. Smaller test holes were drilled through the slab at varying distances from the suction hole. Static vacuum and air flow measurements were conducted at each suction hole location. A micro manometer was used to measure pressure differentials at the EPA sampling ports and test holes. As noted in the table in section 4.2 each slab section has different sub slab material with a divergent range of permeability. Depressurizing denser soils will require low airflow high vacuum blowers while the area with crushed stone will require lower vacuum higher airflow blowers. The Vacuum field and air flow measurements are listed on the table below and grouped by numbered area with the suction holes and test ports referenced on the building diagram.



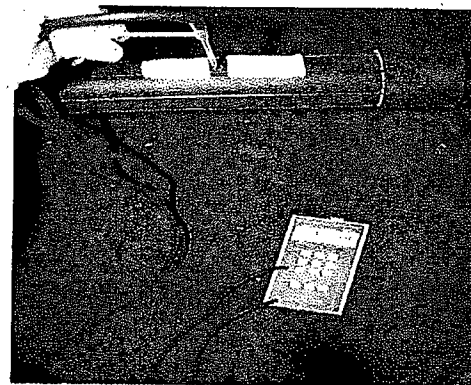
Suction Applied



Micromanometer



Static Vacuum Measured



Air Flow Measurement

89 Morris Street Property, Morristown, NJ Phase II

89 Morris St. Dry Cleaners April 25, 2007

Dry Cleaners Area 10

Suction Hole S-11, Raised wood floor Area 10.6

| Applied Vacuum at Suction Point Measured in Inches of W.C. | Actual Vacuum Measured in Inches of W.C. | Air Flow Measured in Cubic Feet Per Minute | Test and Sample Floor Point | Distance from Suction Point | Vacuum at Sample Point in Inches of W.C. |
|--|--|--|-----------------------------|-----------------------------|--|
| SHOP VAC 50 | 12 | 117 | 30 | 18' 8" | 0.0057 |
| SHOP VAC 50 | 12 | 117 | 31 | 1' 6" | 0.1280 |
| SHOP VAC 50 | 12 | 117 | 32 | 8' 11" | 0.2675 |
| SHOP VAC 50 | 12 | 117 | 33 | 23' 6" | 0.0067 |
| SHOP VAC 50 | 12 | 117 | 36 | 36' 3" | 0.0165 |

Suction Hole S-12, Raised wood floor Area 10.6

| Applied Vacuum at Suction Point Measured in Inches of W.C. | Actual Vacuum Measured in Inches of W.C. | Air Flow Measured in Cubic Feet Per Minute | Test and Sample Floor Point | Distance from Suction Point | Vacuum at Sample Point in Inches of W.C. |
|--|--|--|-----------------------------|-----------------------------|--|
| SHOP VAC 50 | 40 | 6.3 | 31 | 12' | 0.0072 |
| SHOP VAC 50 | 40 | 6.3 | 32 | 1' 6" | 0.0125 |
| SHOP VAC 50 | 40 | 6.3 | 33 | 13' 10" | 0.0169 |
| SHOP VAC 50 | 40 | 6.3 | 34 | 14' | No net change |
| SHOP VAC 50 | 40 | 6.3 | 35 | 25' 3" | 0.0048 |
| SHOP VAC 50 | 40 | 6.3 | 36 | 35' | 0.0111 |
| SHOP VAC 50 | 40 | 6.3 | 37 | 32' 6" | 0.0017 |

Suction Hole S-13, Hanging laundry, Boiler room Area 10.5

| Applied Vacuum at Suction Point Measured in Inches of W.C. | Actual Vacuum Measured in Inches of W.C. | Air Flow Measured in Cubic Feet Per Minute | Test and Sample Floor Point | Distance from Suction Point | Vacuum at Sample Point in Inches of W.C. |
|--|--|--|-----------------------------|-----------------------------|--|
| SHOP VAC 50 | 11 | 137 | 38 | 1' 6" | 1.340 |
| SHOP VAC 50 | 11 | 137 | 39 | 13' 6" | 0.209 |
| SHOP VAC 50 | 11 | 137 | 36 | 13' | 0.029 |

Suction Hole S-14, Office Area Area 10.1

| Applied Vacuum at Suction Point Measured in Inches of W.C. | Actual Vacuum Measured in Inches of W.C. | Air Flow Measured in Cubic Feet Per Minute | Test and Sample Floor Point | Distance from Suction Point | Vacuum at Sample Point in Inches of W.C. |
|--|--|--|-----------------------------|-----------------------------|--|
| SHOP VAC 50 | 44 | 15.6 | 42 | 21' 6" | 0.043 |
| SHOP VAC 50 | 44 | 15.6 | 43 | 1' | 1.08 |

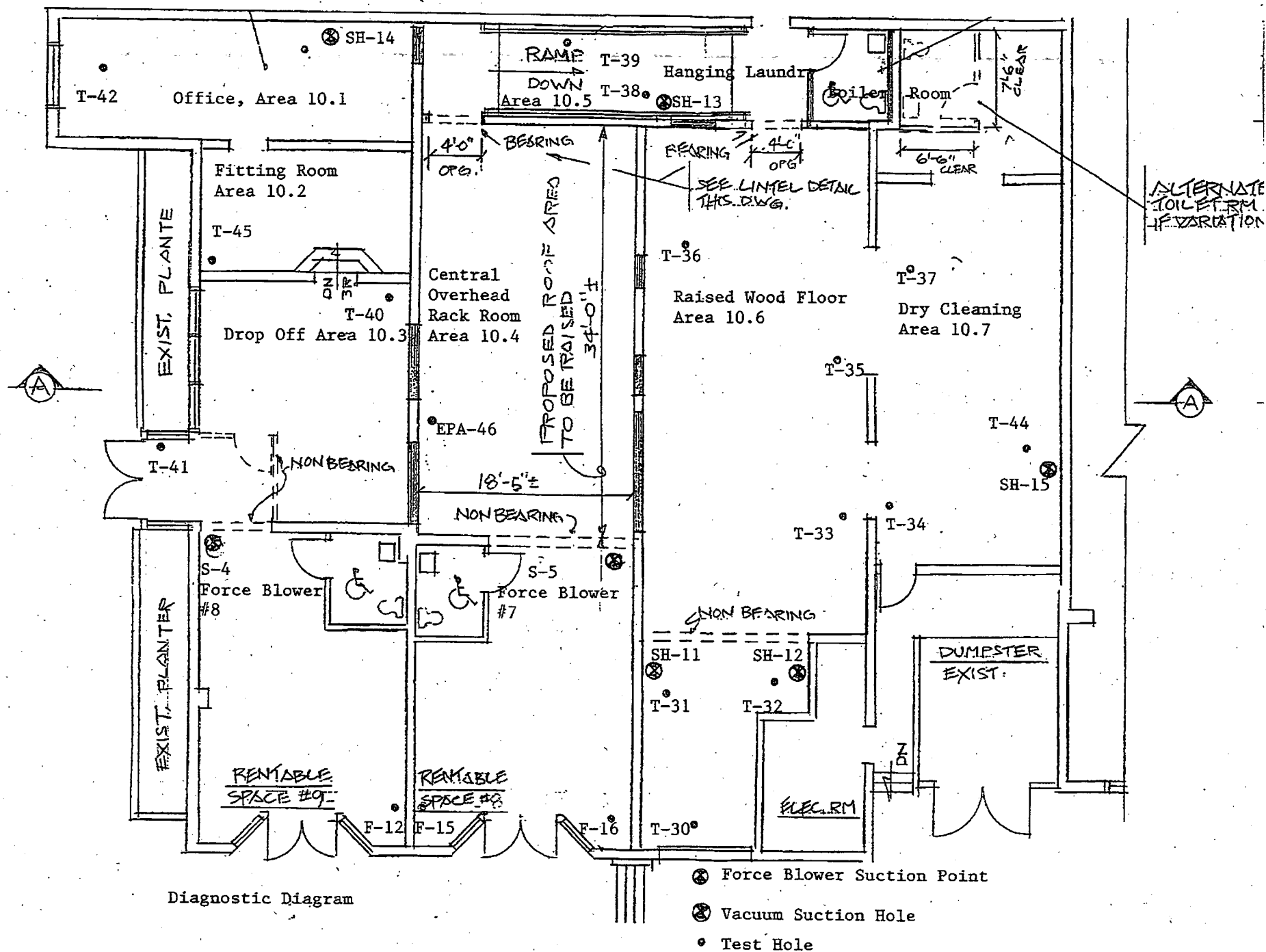
Suction Hole S-15, Dry Cleaning Area 10.7

| Applied Vacuum at Suction Point Measured in Inches of W.C. | Actual Vacuum Measured in Inches of W.C. | Air Flow Measured in Cubic Feet Per Minute | Test and Sample Floor Point | Distance from Suction Point | Vacuum at Sample Point in Inches of W.C. |
|--|--|--|-----------------------------|-----------------------------|--|
| SHOP VAC 50 | 11 | 118 | 34 | 13' 2" | 0.0061 |
| SHOP VAC 50 | 11 | 118 | 37 | 20' | 0.0011 |
| SHOP VAC 50 | 11 | 118 | 35 | 19' 1" | 0.0021 |
| SHOP VAC 50 | 11 | 118 | 44 | 1' 6" | 1.8 |

89 Morris Street Property, Morristown, NJ Phase II

Sub Slab Vacuum Field Measurements From Existing Blowers

| <u>Service Area</u> | <u>Blower # on Print</u> | <u>Blower Type</u> | <u>Suction Points</u> | <u>Maximum Vacuum</u> | <u>Maximum Air Flow</u> | <u>Manometer Reading Inches W.C.</u> | <u>Blower Exhaust CFM</u> |
|------------------------|------------------------------------|-----------------------------------|------------------------------|-----------------------|-------------------------|--------------------------------------|---------------------------|
| Blower 7 | | | | | | | |
| Rental Area 8 | 7 | AMG Force | 1 | 5.5 | 240 | 2.6 | 140 |
| <u>Floor Test Hole</u> | <u>Distance from Suction Point</u> | <u>SubSlab Vacuum Inches W.C.</u> | <u>Location of Test Hole</u> | | | | |
| F-15 | 29 feet | 0.0040 | Rental | Area 8 | | | |
| F-16 | 37 feet | 0.0020 | Rental | Area 8 | | | |
| 46-EPA | 22 feet 8 In | 0.0351 | Central | clothes rack | | | |
| Blower 8 | | | | | | | |
| Rental Area 9 | 8 | AMG Force | 1 | 5.5 | 240 | 3.9 | 84 |
| <u>Floor Test Hole</u> | <u>Distance from Suction Point</u> | <u>SubSlab Vacuum Inches W.C.</u> | <u>Location of Test Hole</u> | | | | |
| F-12 | 18 feet | 0.0053 | Rental | Area 9 | | | |
| F-40 | 26 feet | .0830 | Clothing | Drop Off | | | |
| F-41 | 10 feet | .1530 | Vestibule | | | | |
| F-45 | 25 feet | .0344 | Fitting | Room | | | |



Diagnostic Diagram

89 Morris Street Property, Morristown, NJ Phase II

6.0 GENERAL SYSTEM DESIGN INFORMATION

Throughout these specifications the Owner or their representative shall be referred to as the "Owner". The selected mitigation contractor shall be referred to as the "Contractor".

7.0 GENERAL INSTALLATION REQUIREMENTS

All portions of the contaminant system will abide by the relevant specifications specified in Section 7.0 to, and including, Section 15.3.

- 7.1** The contaminant mitigation system installation shall be done so as to coordinate with other building components especially those that require maintenance or clearance of any type. All mitigation system components shall be installed to facilitate servicing, maintenance and repair or replacement of other equipment components in or outside the building. Where mounting heights are not detailed or dimensions given, system materials and equipment are to be installed to provide the maximum headroom or side clearance as is possible. The Owner must be contacted in cases where a conflict exists between these or other requirements and the drawings or specifications. All systems, materials and equipment shall be installed level, plumb, parallel or perpendicular to other building systems and components unless otherwise specified.
- 7.2** The Contractor shall take every possible precaution to avoid any damage to existing utilities located anywhere in the building or those located in or below the slab floor. It is our understanding that the blueprints indicating utility piping in or under the slab are not available. Undocumented sub-slab utilities may alter the scope of work. A metal detecting relay box or another similar instrument will be used in conjunction with any slab drilling.
- 7.3** The Owner will be responsible for covering or finishing any contaminant piping or electrical conduit that the owner desires to conceal. The Contractor shall seal all penetrations through foundation walls or floors. There shall be no placement of piping or conduit that would inhibit intended use of any areas.
- 7.4** The Contractor shall ensure that any foreign materials are not left or drawn into the contaminant system piping or fan which might at a later period interfere with or in any way impair the contaminant system performance.
- 7.5** The entire system shall have UL or equivalent ratings for both individual components and the entire system as applicable.

89 Morris Street Property, Morristown, NJ Phase II

8.0 SYSTEM MATERIALS

Contaminant Vent Piping

PVC schedule 40 pipe and fittings (ASTM D-2665)

(Foam core PVC piping can be used)

PVC cement primer shall comply with ASTM F-656

PVC cement adhesive shall comply with ASTM D-2564

Piping Supports

3" and 4" Hanging Pipe Supports

Swivel ring or standard bolt type clevis

Adjustable band hanger

Sammy Screws or Drop in Anchors

3/8" threaded rod

Assorted bolts, nuts & washers

3" and 4" Pipe Secured to Concrete Floor or Wall

Slotted Conduit Channel

Conduit Clamps

3/8" Wedge Anchors

Assorted bolts, nuts & washers

Contaminant Fan

Fantech HP 220

AMG Force Blower

RadonAway GP 501

4" to 6" rubber boots with stainless steel hose clamps

4" to 4" rubber boots with stainless steel hose clamps

3" to 3" rubber boots with stainless steel hose clamps

Sealing Materials

Urethane sealant shall comply with Federal Specification TT-S-00230C, Subject to compliance with Contract requirements; the following manufacturers of urethane caulking sealants may be used:

Pecora Corp. (Dynatrol)

Mameco Inc. (Vulkem or CR Lawrence)

Visual pressure indicator

U-tube manometer

89 Morris Street Property, Morristown, NJ Phase II

9.0 SUCTION HOLE INSTALLATION

- 9.1** In order to achieve the vacuum field distribution and not disrupt building use objectives, each of the six suction points will be located in near exterior or partition walls. The specific location of each suction hole will be agreed upon by the contractor and owner prior to initiating remediation. Each suction hole will be cut approximately 5" in diameter. The Contractor will follow the procedures listed in Section 7.2 to minimize damaging any sub-slab utilities.
- 9.2** The Contractor shall remove a minimum of one cubic foot of sub-slab material from each suction hole. Primary suction points will consist of PVC schedule 40 pipe shall be installed so that it is flush with the bottom of the concrete slab in each suction hole. The pipe shall be secured above the suction hole with a pipe clamp attached to the concrete ceiling, cement wall or concrete floor. The pipe will be sealed into each suction hole by inserting backer rod material of sufficient size to compress between the pipe and the concrete floor. Urethane gun-grade caulking or mortar mix will be installed on top of the backer rod.
- 9.3** There are a total of 7 suction points to be installed. (See Suction Point Location on the Building Diagram Page 12)
- 9.4** Disposing of soil excavated from the suction points is the responsibility of the owner.

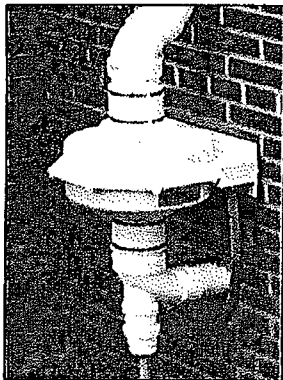
10.0 PVC PIPE INSTALLATION

- 10.1** All horizontal pipe runs between the fan and the first suction hole shall be installed with 1 inch slope back to a suction hole for each ten feet of horizontal pipe run. All vertical pipe runs shall be installed plumb. All horizontal runs after the first suction hole may be run level. In no case however shall the piping be installed so as to create a possible water trap in the piping.
- 10.2** The pipe will be supported at least every eight feet of horizontal run and at least every ten feet of vertical run. All horizontal pipe runs will have a support with an appropriate device within two feet of each fitting and a maximum distance between supports of eight feet as per BOCA National Plumbing Code. The ceiling supporting devices shall be a 3/8 inch all thread rod to structural members capable of providing the necessary support. Conduit channel with pipe clamps can also be used to support PVC routed along the ceiling or walls. PVC pipe cannot be supported by other building piping or ducts. Swivel ring or standard bolt type clevis shall be used to support PVC pipe.
- 10.3** All support straps and anchors installed outdoors shall be either aluminum, stainless steel or galvanized.

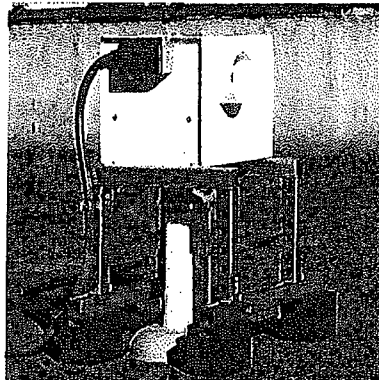
89 Morris Street Property, Morristown, NJ Phase II

11.0 BLOWER INSTALLATION

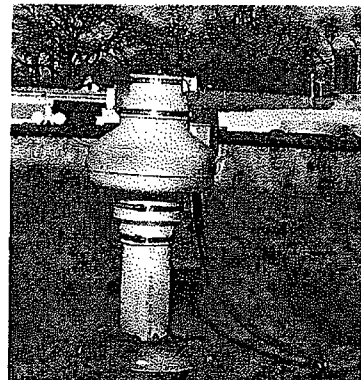
- 11.1 There will be total of five roof mounted blowers, three Fantech HP 220 blowers, one RadonAway GP 501 blower and one AMG Force high suction blower. The AMG Force blower will be mounted on a galvanized stands with high density foam rubber blocks separating the metal stands from the roofing material. The Fantech HP 220 blowers will be attached to the riser pipe with rubber boots in a manner that allows easy removal for replacement or maintenance. (See contaminant Blower-Detail Section, pg. 16-23)
- 11.2 The locations of the blowers are noted on the print. The AMG Force blowers are symbolized by an orange square with a dot in the center and the Fantech HP 220 Blowers are symbolized by an orange circle with a dot in the center. Blower exhaust shall be at least 20 from air intakes, passive relief vents and 10 feet from lot lines.



GP 501 Blower



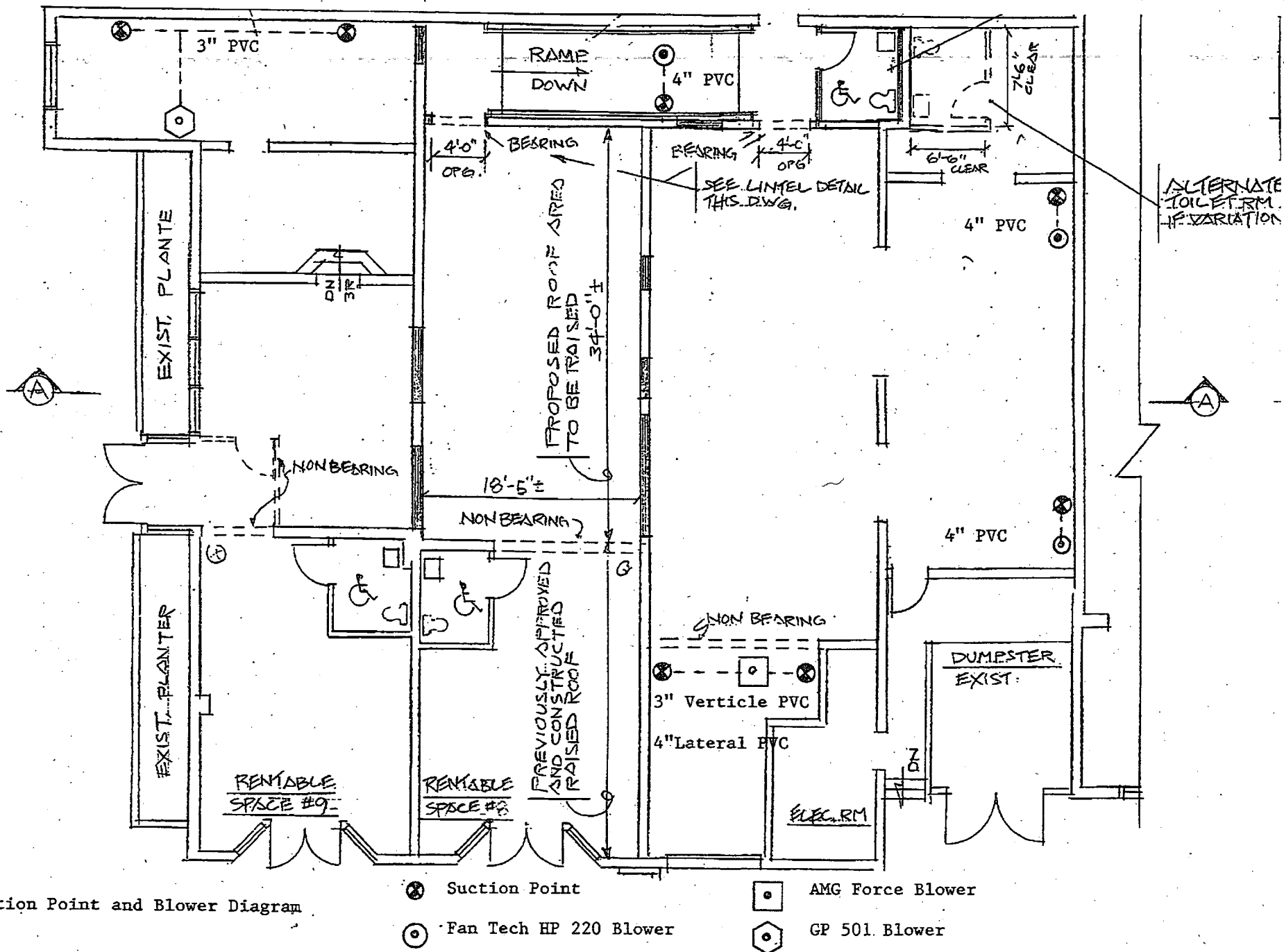
AMG Force Blower



HP 220 Blower

12.0 ROOF PENETRATIONS

- 12.1 All roof penetrations must be coordinated with the Owner prior to performing the work. The Contractor will make the penetration through the roof. The Owners roofing shall perform the flashing related sealing work.
- 12.2 The building owner is responsible for sub-contracting the roofing contractor to install the sealing for pipe and conduit roof penetrations.



Suction Point and Blower Diagram

89 Morris Street Property, Morristown, NJ Phase II

13.0 SEALING

13.1 Slab Crack and Expansion Joint Sealing

Any visible expansion joints or slab cracks in the areas being mitigated that have 1/16 inch or greater opening shall be sealed. Any cracks to be sealed will first be ground out and vacuumed to prepare them for installation of gun-grade urethane caulk sealant. Cracks or open expansion joints in the concrete floor shall be sealed by applying a bead of urethane caulk on top of the joint. The gun-grade caulk shall then be mechanically pressed down into the crack in order to maximize its seal. Sealants that spill over onto the floor shall be scraped off as soon as possible and then wiped thoroughly with a solvent and a rag. Any openings into the slab such as may occur around conduit pipe penetrations through the slab will be cleaned and sealed with gun-grade urethane caulk.

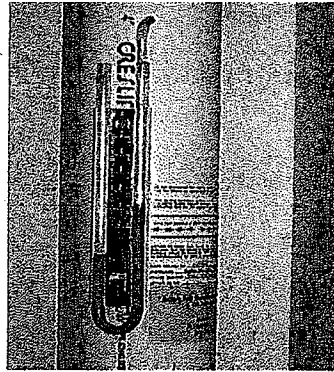
13.2 Perimeter Expansion Joint

Any expansion strips in the concrete slab of the rooms being mitigated that are accessible shall be sealed with urethane caulking. The perimeter floor joint will be sealed with gun-grade urethane caulking after the joint has been vacuumed.

14.0 FAN WIRING AND PRESSURE GAUGE

- 14.1** The owner is responsible for providing electrical panel capacity. A dedicated breaker is not required.
- 14.2** The owner will install, within two feet of each blower a roof mounted disconnect switch in an outdoor rated electrical box with an outdoor rated switch cover.
- 14.3** The Contractor is responsible for providing conduit, wiring and electrical power from the switch to the blower. The Contractor shall use outdoor rated flexible conduit from each switch box to the blower. Wiring from the switch box to the blower shall be approved individual 12 gauge wire.
- 14.4** The Fantech Blower has a maximum amperage draw of less than 2 amps and a voltage requirement of 110 volts. The specified AMG Force blower has a maximum amperage draw of less than 2.48 amps and a voltage requirement of 120 volts. The RadonAway GP 501 Blower has a maximum amperage draw of less than 2 amps and a voltage requirement of 110 volts.
- 14.5** A U-tube manometer will be installed for each fan by the Contractor on a vertical section of the piping inside the building. The location of the U-tube will be decided in consultation with the Owner.

89 Morris Street Property, Morristown, NJ Phase II



Liquid Filled Manometer

15.0 SYSTEM LABELING

- 15.1 A label will be installed at the disconnect switch next to the fan that says "Active Soil Depressurization System, Do not alter." The breaker number powering the fan shall be indicated on the same disconnect switch. The electrical circuit at the main panel that is used to control the fan shall be labeled as "Active Soil Depressurization System."
- 15.2 All U-tube manometer locations shall contain a label explaining their use and be marked with the installation date and final installation U-tube pressure readings. At least every 20 feet of contaminant vent pipe length shall have a label that reads "Active Soil Depressurization System" attached to the pipe. All labels must be readable from 3 feet away.
- 15.3 The Contractors name, telephone number and date of installation, shall be left at the main panel that powers each contaminant system.

16.0 FINAL VACUUM TEST

- 16.1 The Contractor shall measure the pressure field extension beneath the sub-slab created by each ASD system. Micro-manometer measurements should be made at each of the original test holes. The Contractor shall record these final pressure readings between the sub-slab and the room in a format similar to the one in section 5.1. The pressure measurements will be made with a digital micro-manometer capable of reading down to 0.001". A copy of these final measurements, including the U-tube measurements, will be maintained by the Contractor and the Owner.

17.0 PERMITS

- 17.1 It is the responsibility of the remediation contractor to secure the municipal permits. The owner's electrician will fill out and seal the electrical permit and provide it to the remediation contractor.
- 17.2 The owner shall arrange and provide building access for the municipal building inspectors to inspect the relevant components of the ASD system.

89 Morris Street Property, Morristown, NJ Phase II

- 17.3** Any additional system components or permits that are not addressed in this scope of work but subsequently required by a municipal, state or federal agency shall constitute a change in scope of work and be addressed as a separate line item cost to the owner.

BLOWER SPECIFICATIONS AND WARRANTIES



Fantech

*Trust the
Industry
Standard!*

Improved UV resistance!

HP Series Fans for Radon Applications

Why put your reputation at stake by installing a fan you know won't perform like a Fantech? For nearly twenty years, Fantech has manufactured quality ventilation equipment for Radon applications. Fantech is the fan Radon contractors have turned to in over 1,000,000 successful Radon Installations worldwide.

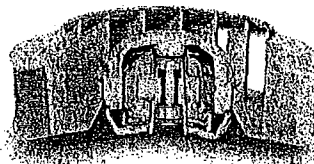
Fantech HP Series Fans Provide the Solutions to meet the challenges of Radon applications:

HOUSING

- UV resistant, UL listed durable plastic
- UL Listed for use in commercial applications
- Factory sealed to prevent leakage
- Watertight electrical terminal box
- Approved for mounting in wet locations - i.e. Outdoors

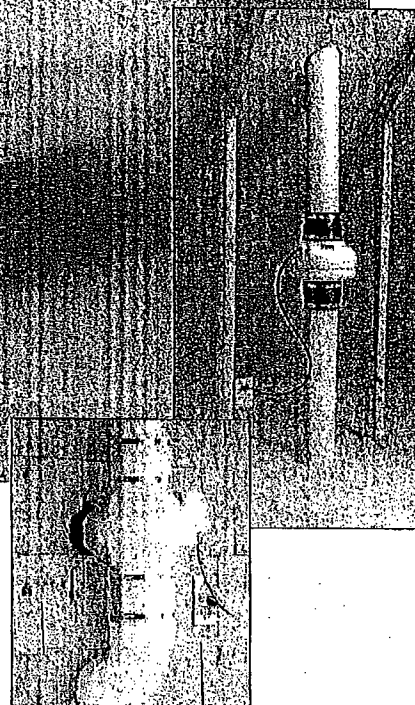
MOTOR

- Totally enclosed for protection
- High efficiency EBM motorized impeller
- Automatic reset thermal overload protection
- Average life expectancy of 7-10 years under continuous load conditions



RELIABILITY

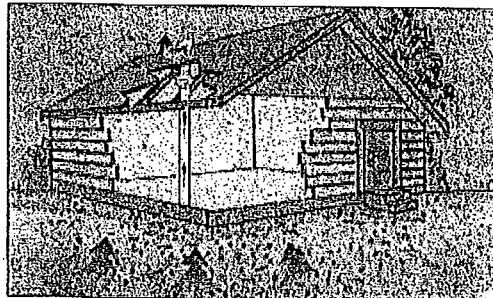
- Five Year Full Factory Warranty
- Over 1,000,000 successful radon installations worldwide





HP Series Fans are specially designed with higher pressure capabilities for Radon Mitigation applications

Fantech has developed the HP Series fans specifically to suit the higher pressure capability requirements needed in Radon Mitigation applications. Most Radon Mitigators who previously used the Fantech FR Series fans have switched to the new HP Series.



Performance Data

| Fan Model | Volts | Wattage Range | Max. Amps | CFM @ Static Pressure in Inches W.G. | | | | | | | | Max. P _s |
|-----------|-------|---------------|-----------|--------------------------------------|------|-------|------|-------|------|-------|------|---------------------|
| | | | | 0" | 0.5" | 0.75" | 1.0" | 1.25" | 1.5" | 1.75" | 2.0" | |
| HP2133 | 115 | 14 - 20 | 0.17 | 134 | 66 | 19 | - | - | - | - | - | 0.84 |
| HP2190 | 115 | 60 - 85 | 0.78 | 163 | 126 | 104 | 81 | 58 | 35 | 15 | - | 1.93 |
| HP175 | 115 | 44 - 65 | 0.67 | 151 | 112 | 91 | 70 | 40 | 12 | - | - | 1.66 |
| HP190 | 115 | 60 - 85 | 0.78 | 157 | 123 | 106 | 89 | 67 | 45 | 18 | 1 | 2.01 |
| HP220 | 115 | 85 - 152 | 1.30 | 344 | 260 | 226 | 193 | 166 | 137 | 102 | 68 | 2.46 |

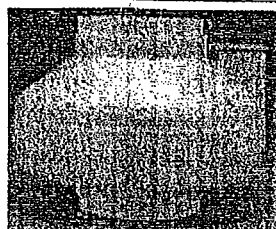
HVI
MEMBER™

Performance Curves

Fantech provides you with independently tested performance specifications.

The performance curves shown in this brochure are representative of the actual test results recorded at Texas Engineering Experiment Station/Energy Systems Lab, a recognized testing authority for HVI. Testing was done in accordance with AMCA Standard 210-85 and HVI 915 Test Procedures. Performance graphs show air flow vs. static pressure.

Use of HP Series fans in low resistance applications such as bathroom venting will result in elevated sound levels. We suggest FR Series or other Fantech fans for such applications.

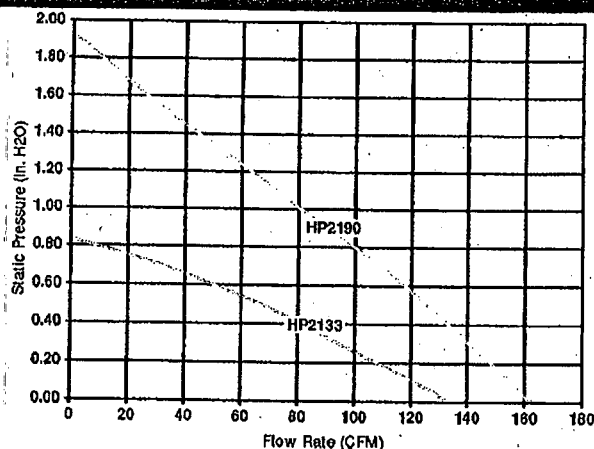


HP FEATURES INCLUDE

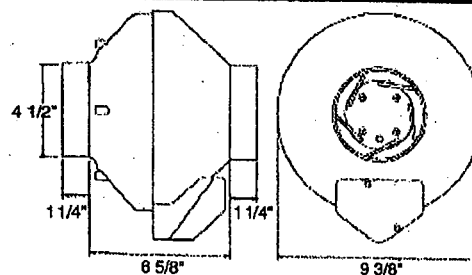
- Improved UV resistant housings approved for commercial applications.
- UL Approved for Wet Locations (Outdoors)
- Sealed housings and wiring boxes to prevent Radon leakage or water penetration
- Energy efficient permanent split capacitor motors
- External wiring box
- Full Three Year Factory Warranty



HP2133 and 2190 Radon Mitigation Fans



Tested with 4" ID duct and standard couplings.

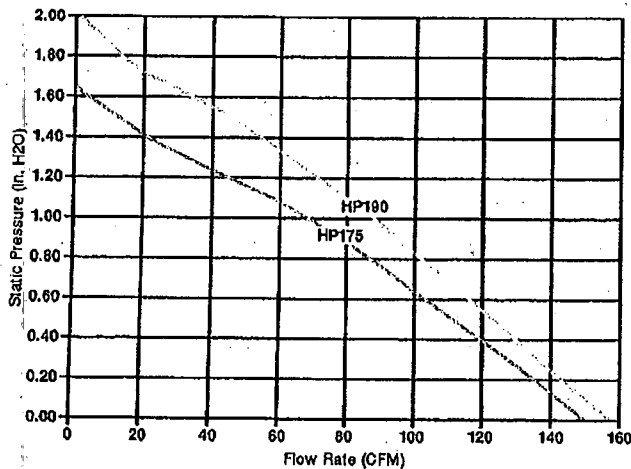


HP2133 - For applications where lower pressure and flow are needed. Record low power consumption of 14-20 watts! Often used where there is good sub slab communication and lower Radon levels.

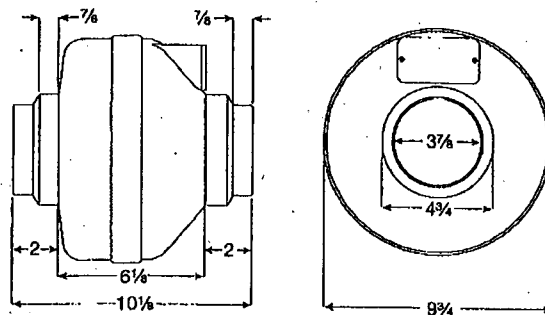
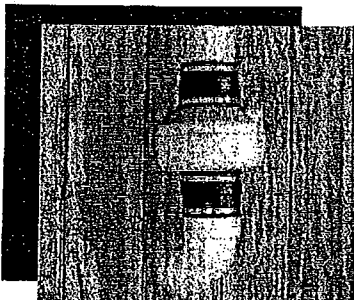
HP2190 - Performance like the HP190 but in a smaller housing. Performance suitable for the majority of installations.

Fans are attached to PVC pipe using flexible couplings. For 4" PVC pipe use Indiana Seals #156-44, Pipeconx PCX 58-44 or equivalent. For 3" PVC pipe use Indiana Seals #156-43, Pipeconx PCX 58-43 or equivalent.

HP175 and HP190 Radon Mitigation Fans



Tested with 4" ID duct and standard couplings.



HP175 – The economical choice where slightly less air flow is needed. Often used where there is good sub slab communication and lower Radon levels.

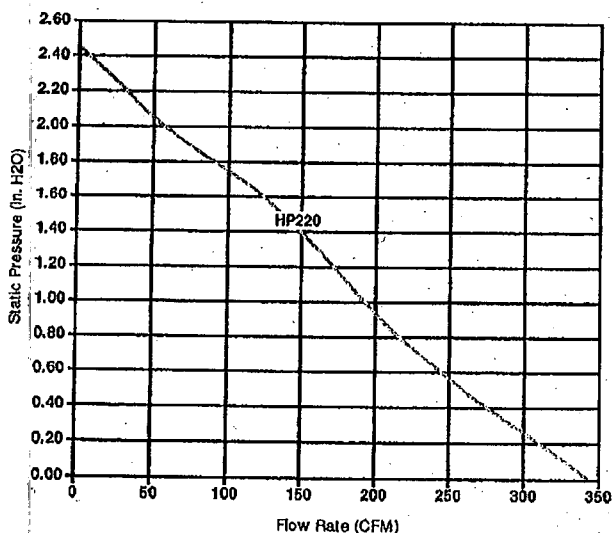
HP190 – *The standard for Radon Mitigation.* Ideally tailored performance curve for a vast majority of your mitigations.

Fans are attached to PVC pipe using flexible couplings.

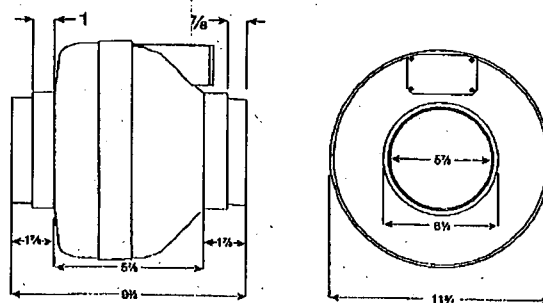
For 4" PVC pipe use Indiana Seals #151-44, Pipeconx PCX 51-44 or equivalent.

For 3" PVC pipe use Indiana Seals #156-43, Pipeconx PCX 56-43 or equivalent.

HP220 Radon Mitigation Fan



Tested with 6" ID duct and standard couplings.



HP 220 – Excellent choice for systems with elevated radon levels, poor communication, multiple suction points and large subslab footprint. Replaces FR 175.

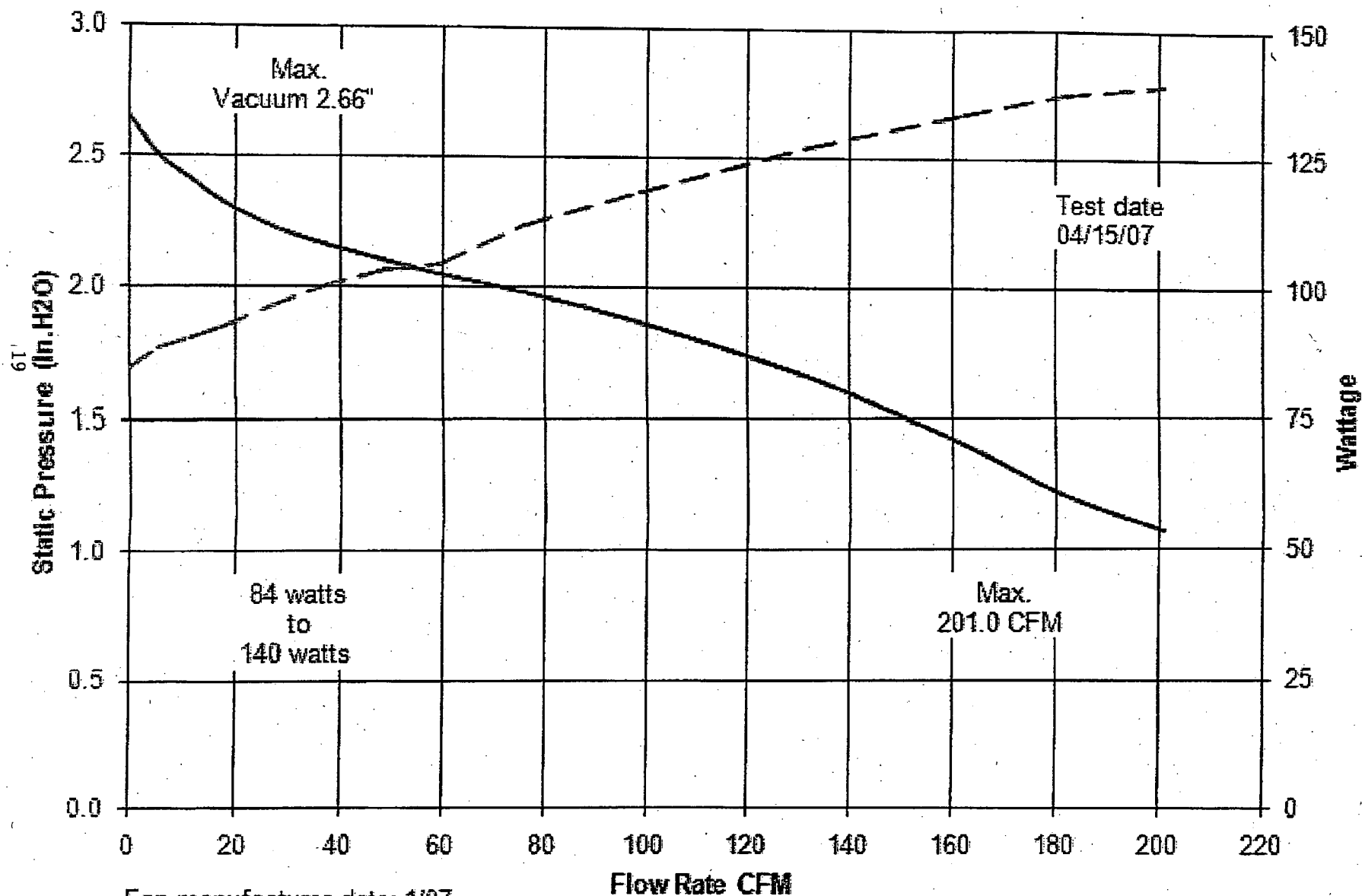
Fans are attached to PVC pipe using flexible couplings.

For 4" PVC pipe use Indiana Seals #156-64, Pipeconx PCX 56-64 or equivalent.

For 3" PVC pipe use Indiana Seals #156-63, Pipeconx PCX 56-63 or equivalent.

FanTech HP220 performance w/10' of 4" pvc pipe

— HP220 - 6 inch
- - - fan wattage

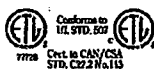
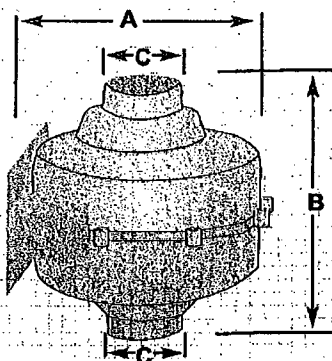
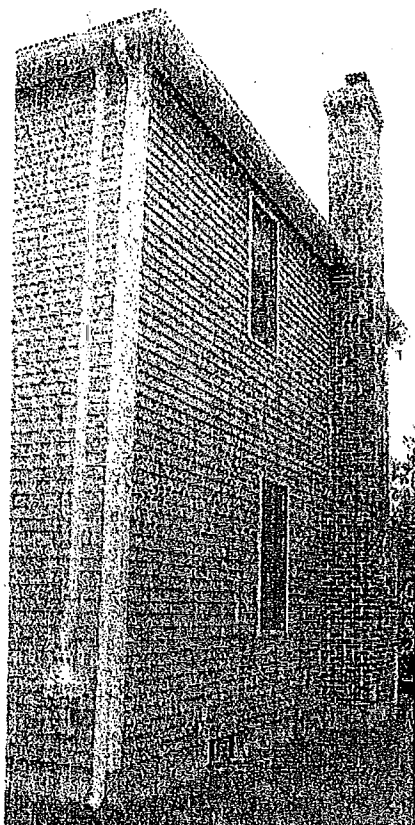
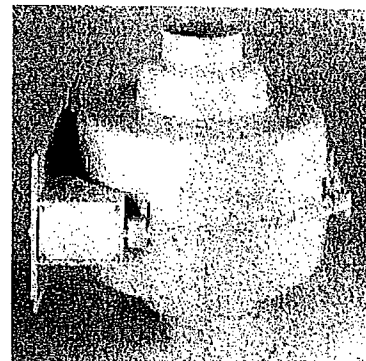


RadonAway™

GP Series

Radon Mitigation Fans

Specially designed for radon mitigation, GP Series Fans provide a wide range of performance that makes them ideal for most subslab radon mitigation systems.



- ♦ 5-Year Warranty
- ♦ Mounts on duct pipe or with integral flange
- ♦ 3" diameter ducts for use with 3" or 4" pipe
- ♦ Electrical box for hard wire or plug in
- ♦ ETL Listed - for indoor or outdoor use.

| Model | Dimensions | | |
|-----------|------------|-----|----------------|
| | A | B | C Duct Size |
| GP series | 12.5" | 13" | 3" |

The following chart shows performance of GP Series fans:

| Model | Watts | Maximum Pressure "WC | Typical CFM vs. Static Pressure WC | | | | | | |
|-------|--------|----------------------|------------------------------------|------|------|------|------|------|------|
| | | | 1.0" | 1.5" | 2.0" | 2.5" | 3.0" | 3.5" | 4.0" |
| GP201 | 40-60 | 2.0 | 82 | 58 | 5 | - | - | - | - |
| GP301 | 55-90 | 2.6 | 92 | 77 | 45 | 10 | - | - | - |
| GP401 | 60-110 | 3.4 | 93 | 82 | 60 | 40 | 15 | - | - |
| GP501 | 70-140 | 4.2 | 95 | 87 | 80 | 70 | 57 | 30 | 10 |

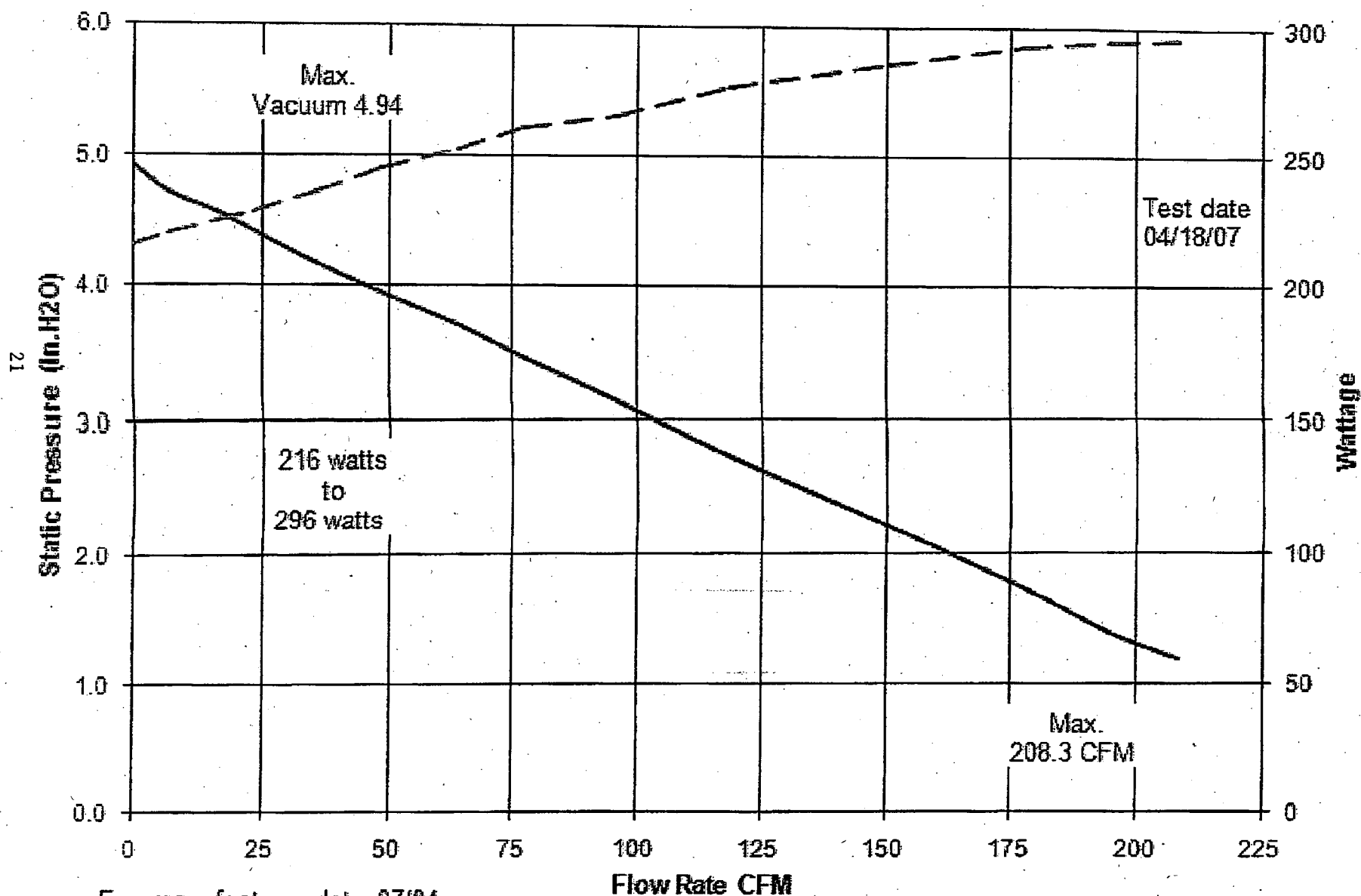
Choice of model is dependent on certain building characteristics including sub-slab materials and should be made by a radon professional.

FOR FURTHER INFORMATION CONTACT:

0902
P/N 02002

AMG Force performance w/10' of 4" pvc pipe

Force - 4 inch
fan wattage



The Force... behold the power

Performance Figures - AMG Force, Radon Extract Fan

| Model | Volts | Watts | Max. Amps | CFM at STATIC PRESSURE in. wg. | | | | | | | | | | | |
|-----------|-----------|-------|-----------|--------------------------------|------|------|------|------|------|------|------|------|------|----|------|
| | | | | 0" | 0.5" | 1.0" | 1.5" | 2.0" | 2.5" | 3.0" | 3.5" | 4.0" | 4.5" | 5" | 5.5" |
| AMG Force | 120V 60Hz | 302 | 2.48 | 240 | 223 | 207 | 191 | 174 | 155 | 133 | 110 | 83 | 55 | 28 | 0 |

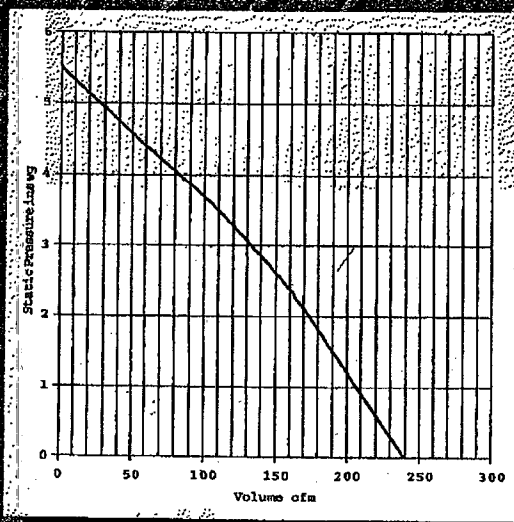
Weight: 19lb

Fan Speed: 2950 rpm

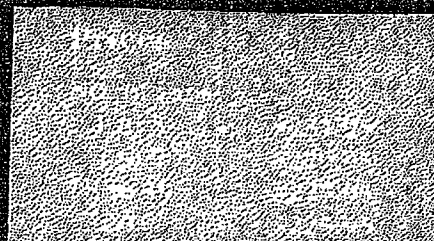
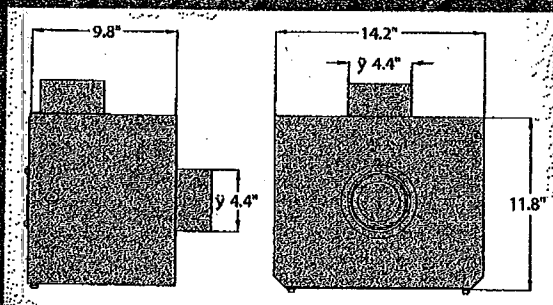
Performance shown is for installation type D -
Ducted inlet, Ducted outlet.
Speed (rpm) shown is nominal. Performance is
based on actual speed of test.

Performance ratings do not include the effects of
appurtenances in the airstream.
The performance figures shown have been
corrected to standard air density.

Performance Graph



Dimensions



Solely distributed throughout the USA
and Canada by:

**Festa Radon
Technologies Co**

634 North Avenue, Pittsburgh, PA 15209

Toll Free: 1(800) 806-7866

Fax: 1(412) 931-0754

RadonAway GP501 performance w/10' of 4" pvc pipe

— GP501 - 3 inch
- - - fan wattage

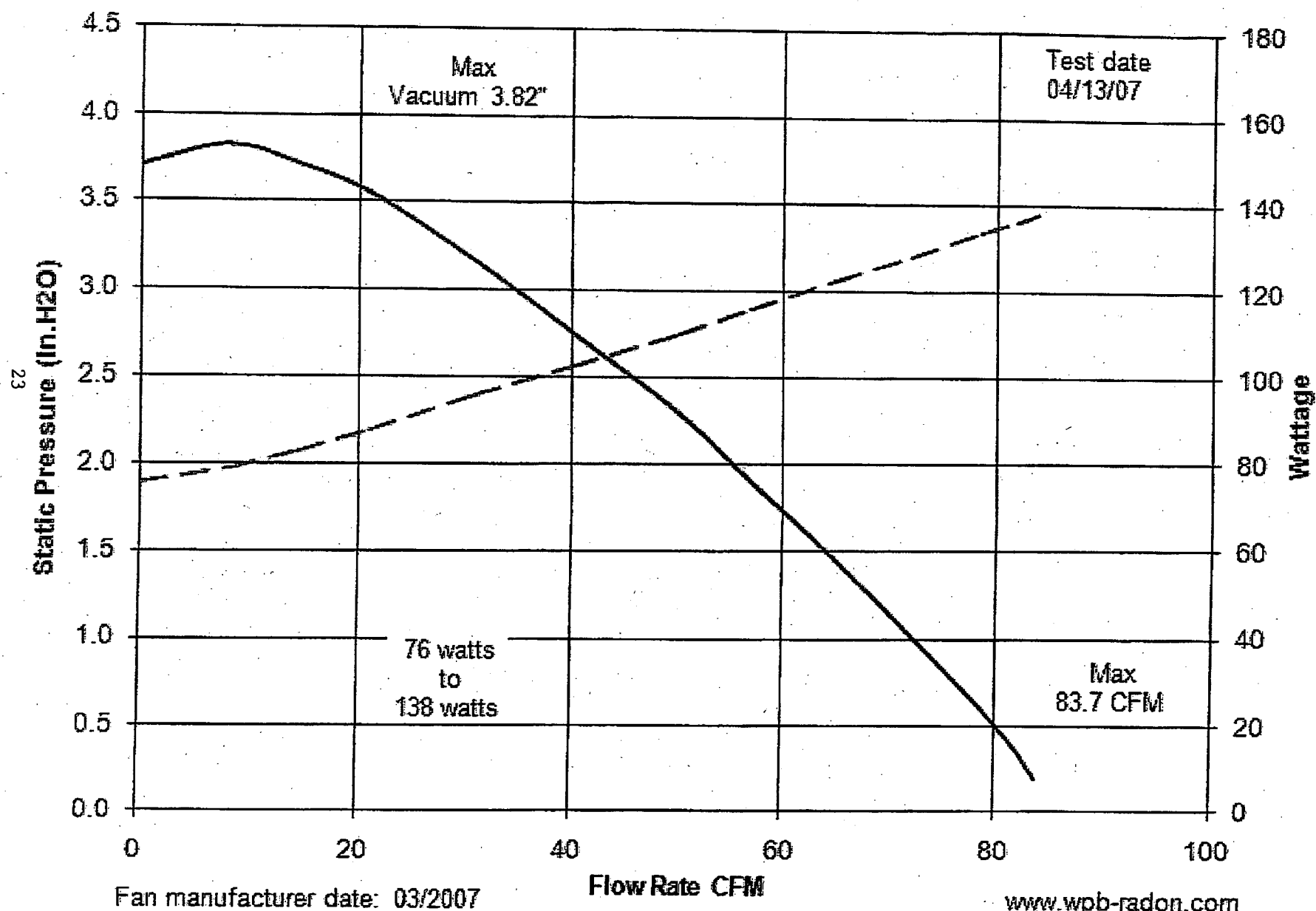


TABLE OF CONTENTS

| | |
|---|------|
| ACKNOWLEDGEMENTS..... | i |
| DISCLAIMER..... | ii |
| TABLE OF CONTENTS..... | iii |
| ABBREVIATION LIST..... | viii |
| 1.0 INTRODUCTION..... | 1 |
| 1.1 Regulatory Basis for the Guidance..... | 1 |
| 1.2 Intended Use of the Guidance..... | 2 |
| 1.3 Overview of the Guidance..... | 3 |
| 1.4 Guidance Updates..... | 5 |
| 2.0 CONCEPTUAL SITE MODEL..... | 6 |
| 2.1 Sources of Vapor Intrusion..... | 8 |
| 2.2 Vapor Migration Mechanisms..... | 8 |
| 2.2.1 Diffusion of vapors from sources in the unsaturated zone..... | 9 |
| 2.2.2 Diffusion of vapors from sources in shallow ground water..... | 10 |
| 2.2.3 Advective/convective transport of vapors..... | 11 |
| 2.2.4 Vapor migration through preferential pathways..... | 13 |
| 2.3 Receptors..... | 15 |
| 2.4 Factors Affecting Vapor Migration..... | 15 |
| 2.4.1 Biodegradation..... | 16 |
| 2.4.2 Site Stratigraphy..... | 16 |
| 2.4.3 Soil Moisture and Ground Water Recharge..... | 18 |
| 2.4.4 Fluctuations in Water Table Elevation..... | 19 |
| 2.4.5 Ventilation Systems in Commercial/Industrial Buildings..... | 21 |
| 3.0 DECISION FRAMEWORK..... | 24 |
| 3.1 Preliminary Assessment and Site Investigation..... | 24 |
| 3.2 Remedial Investigation..... | 27 |
| 3.3 Site-Specific Screening Options..... | 29 |
| 3.4 Remediation and Monitoring..... | 31 |
| 4.0 GENERIC VAPOR INTRUSION SCREENING LEVELS..... | 32 |
| 4.1 Introduction..... | 32 |
| 4.2 Ground Water Screening Levels..... | 32 |
| 4.2.1 Application of the Ground Water Screening Levels..... | 33 |
| 4.2.2 Degradation of BTEX Chemicals..... | 35 |
| 4.3 Indoor Air Screening Levels..... | 35 |
| 4.3.1 Application of the Indoor Air Screening Levels..... | 35 |
| 4.3.2 Alternate Indoor Air Screening Levels..... | 36 |
| 4.3.3 Rapid Action and Health Department Notification Levels..... | 37 |
| 4.4 Soil Gas Screening Levels..... | 38 |
| 5.0 SITE-SPECIFIC SCREENING PROCEDURES..... | 39 |
| 5.1 Default Screening Numbers for Alternate Soil Textures..... | 39 |

| | | |
|---------|---|----|
| 5.2 | Site-Specific Use of the J&E Model for Calculation of VI GWSL..... | 39 |
| 5.2.1 | Chemical Properties | 40 |
| 5.2.2 | Toxicological and Exposure Parameters | 40 |
| 5.2.3 | Soil Texture | 41 |
| 5.2.4 | Soil Physical and Chemical Properties | 43 |
| 5.2.5 | Building Parameters | 44 |
| 5.2.6 | Depth to Ground Water | 47 |
| 5.2.7 | Summary of Site-Specific J&E Modeling for Calculation of GWSL for the VI Pathway | 47 |
| 5.3 | Additional Site-Specific Options | 48 |
| 6.0 | SAMPLING PROCEDURES AND INVESTIGATION REQUIREMENTS | 50 |
| 6.1 | Preparation of a Vapor Intrusion Workplan | 50 |
| 6.1.1 | Conceptual Site Model | 50 |
| 6.1.2 | General Issues | 51 |
| 6.1.3 | Investigative Tools | 51 |
| 6.1.3.1 | Ground Water Sampling | 52 |
| 6.1.3.2 | Soil Gas Sampling | 52 |
| 6.1.3.3 | Indoor Air Sampling | 55 |
| 6.1.3.4 | Soil Sampling | 57 |
| 6.1.4 | Preferential Pathways | 57 |
| 6.1.5 | VI Report Requirements | 58 |
| 6.2 | Ground Water Investigation and Sampling Procedures | 59 |
| 6.2.1 | Saturated Zone Features Affecting Vapor Intrusion | 59 |
| 6.2.1.1 | Clean Water Lens | 59 |
| 6.2.1.2 | Depth to Saturated Zone and Stratigraphy | 61 |
| 6.2.1.3 | Fluctuation in Depth to Saturated Zone | 62 |
| 6.2.1.4 | Complex Hydrogeologic Settings | 62 |
| 6.2.1.5 | Proximity to Preferential Pathways | 63 |
| 6.2.1.6 | Potential for Contaminant Degradation | 63 |
| 6.2.2 | Use of Pre-Existing Ground Water Data | 64 |
| 6.2.2.1 | Interpolation of Nearby Data | 64 |
| 6.2.2.2 | Use of Drinking Water Well Data | 65 |
| 6.2.3 | Obtaining New Ground Water Data to Evaluate the VI Pathway | 65 |
| 6.2.3.1 | Ground Water Sampling Location | 66 |
| 6.2.3.2 | Sampling Depth Intervals | 67 |
| 6.2.3.3 | Direct Push and Alternative Ground Water Sampling Methods | 69 |
| 6.2.3.4 | Monitoring Well Sampling Methods for VI Investigations | 70 |
| 6.2.3.5 | Installation of New Monitor Wells | 73 |
| 6.2.3.6 | Ongoing Ground Water Monitoring | 74 |
| 6.3 | Exterior or Near Slab Soil Gas Sampling Procedures | 75 |
| 6.3.1 | Application | 75 |
| 6.3.1.1 | Stand-Alone assessment of the VI pathway (Near Slab Only) | 76 |
| 6.3.1.2 | Field screening | 77 |
| 6.3.1.3 | Evaluating contaminant patterns | 78 |
| 6.3.1.4 | Assessing background contamination | 78 |
| 6.3.2 | Sampling Procedure | 78 |
| 6.3.2.1 | Site Conditions | 78 |
| 6.3.2.2 | Soil Gas Sampling | 79 |
| 6.3.2.3 | Annular Seal and Tracer Gas | 80 |
| 6.3.2.4 | Sample Containers and Analytical Methods | 81 |
| 6.3.2.5 | Purge Volumes | 84 |
| 6.3.2.6 | Sample Flow Rate | 84 |
| 6.3.2.7 | Sample Locations | 85 |
| 6.3.2.8 | Number of Samples | 85 |

| | | |
|----------|--|-----|
| 6.3.2.9 | Sample Frequency..... | 86 |
| 6.3.2.10 | Underground Utilities..... | 86 |
| 6.3.2.11 | License Requirements..... | 87 |
| 6.3.2.12 | Passive Sample Collection Methodologies..... | 87 |
| 6.3.2.13 | Undeveloped Parcels and Future Use..... | 88 |
| 6.3.2.14 | Data Evaluation..... | 89 |
| 6.4 | Sub-Slab Soil Gas Sampling Procedures..... | 89 |
| 6.4.1 | Application..... | 90 |
| 6.4.1.1 | Stand-Alone Assessment of the VI Pathway..... | 90 |
| 6.4.1.2 | Evaluating Contaminant Patterns..... | 91 |
| 6.4.1.3 | Assessing Background Contamination..... | 92 |
| 6.4.2 | Sampling Procedure..... | 92 |
| 6.4.2.1 | Permanent Sample Point Approach..... | 93 |
| 6.4.2.2 | Temporary Sample Point Approach..... | 95 |
| 6.4.2.3 | Sample Containers and Analytical Methods..... | 95 |
| 6.4.2.4 | Sample Flow Rate..... | 96 |
| 6.4.2.5 | Calculating Purge Volumes..... | 97 |
| 6.4.2.6 | Sample Location..... | 97 |
| 6.4.2.7 | Number of Sample Points..... | 97 |
| 6.4.2.8 | Sample Frequency..... | 98 |
| 6.4.3 | Data Evaluation..... | 98 |
| 6.5 | Conducting A Building Walkthrough and Survey..... | 99 |
| 6.5.1 | Detection of Potential Background Sources..... | 100 |
| 6.5.2 | Recognition of Points of Vapor Intrusion in a Structure..... | 102 |
| 6.5.3 | Identification of Possible Sample Locations..... | 102 |
| 6.5.4 | Education of the Occupants on Vapor Intrusion and Sampling Procedures..... | 103 |
| 6.6 | Indoor Air Sampling Procedures..... | 104 |
| 6.6.1 | Application..... | 105 |
| 6.6.1.1 | Stand-Alone assessment of the vapor intrusion pathway..... | 105 |
| 6.6.1.2 | Evaluating contaminant patterns..... | 105 |
| 6.6.1.3 | Assessing background contamination..... | 106 |
| 6.6.2 | Sampling Procedures and Analytical Methods..... | 106 |
| 6.6.2.1 | TO-15 Requirements..... | 107 |
| 6.6.2.2 | TO-17 Requirements..... | 108 |
| 6.6.2.3 | Number of Sample Locations..... | 109 |
| 6.6.2.4 | Sample Frequency..... | 110 |
| 6.6.2.5 | Pressure and Temperature Issues..... | 110 |
| 6.6.3 | Data Evaluation..... | 111 |
| 7.0 | EVALUATION OF ANALYTICAL RESULTS..... | 112 |
| 7.1 | Background Sources..... | 112 |
| 7.2 | Ground Water Samples..... | 112 |
| 7.3 | Vertical Ground Water Contaminant Profile..... | 113 |
| 7.4 | Sub-Slab Soil Gas Samples..... | 114 |
| 7.5 | Indoor Air Samples from the Basement..... | 115 |
| 7.6 | Multiple Indoor Air Samples from Different Floors..... | 116 |
| 7.7 | Indoor Air and Sub-Slab Soil Gas Samples..... | 117 |
| 7.8 | Indoor Air Data Evaluation..... | 120 |
| 7.9 | Official Notification..... | 121 |
| 8.0 | BACKGROUND CONTAMINATION..... | 123 |
| 8.1 | Background Investigations..... | 123 |
| 8.2 | Background Indoor Air Sources..... | 124 |
| 8.3 | Methods to Address Background Sources..... | 126 |
| 8.3.1 | Primary Factors..... | 126 |

| | | |
|----------|--|-----|
| 8.3.1.1 | Site-Specific Contaminants of Concern | 126 |
| 8.3.1.2 | Sub-slab soil gas sampling..... | 127 |
| 8.3.1.3 | Ambient (outdoor) air sampling..... | 128 |
| 8.3.2 | Secondary Factors | 128 |
| 8.3.2.1 | Building survey..... | 128 |
| 8.3.2.2 | Indoor air background databases..... | 129 |
| 8.3.2.3 | Exterior soil gas sampling..... | 130 |
| 8.3.3 | Other Issues | 130 |
| 9.0 | PETROLEUM HYDROCARBONS..... | 132 |
| 9.1 | Introduction..... | 132 |
| 9.2 | Biodegradation | 133 |
| 9.3 | Site Evaluation..... | 134 |
| 10.0 | REMEDIAL ACTION..... | 135 |
| 10.1 | Remedial Action Techniques..... | 135 |
| 10.1.1 | Subsurface Depressurization Systems: | 136 |
| 10.2 | Remedial Action Implementation..... | 137 |
| 10.2.1 | Remedial Action System Requirements..... | 137 |
| 10.2.2 | Qualifications | 138 |
| 10.2.3 | Permits..... | 138 |
| 10.2.4 | Pre-Construction Considerations | 139 |
| 10.3 | Remedial Action Operation, Monitoring and Maintenance | 140 |
| 10.3.1 | Institutional and Engineering Controls | 140 |
| 10.3.2 | Remedial Action System Verification Sampling, Monitoring and Maintenance | 141 |
| 10.3.2.1 | Verification Procedures..... | 141 |
| 10.3.2.2 | Monitoring and Maintenance | 142 |
| 10.3.2.3 | Remedial Action Progress Report Submission..... | 143 |
| 10.3.2.4 | System Termination Sampling..... | 143 |
| 11.0 | COMMUNITY OUTREACH FOR VAPOR INTRUSION SITES..... | 148 |
| 11.1 | About the Office of Community Relations | 148 |
| 11.2 | Why Do Community Outreach? | 148 |
| 11.3 | Communicating with the Public about Vapor Intrusion..... | 149 |
| 11.3.1 | Local Officials | 149 |
| 11.3.2 | General Public..... | 149 |
| 11.3.3 | Media..... | 150 |
| 11.4 | Arranging Sample Appointments | 150 |
| 11.4.1 | Letters..... | 151 |
| 11.4.2 | Phone Calls..... | 152 |
| 11.5 | Collecting Samples..... | 153 |
| 11.6 | Reporting Sample Results | 153 |
| 11.6.1 | Verbal Reports..... | 154 |
| 11.6.2 | Written Reports..... | 154 |
| 11.7 | Community Outreach during Remedial Actions..... | 156 |
| 11.8 | Meeting with the Public | 156 |
| 11.9 | Additional Information..... | 158 |

TABLES

Table 1 - NJDEP Master Table (Generic Vapor Intrusion Screening Levels)

Table 2 - NJDEP Rapid Action and Health Department Notification Levels

Table 3 - Ground Water Screening Levels for Alternate Soil Textures

| | |
|-------------------|--|
| <i>APPENDIX A</i> | <i>Decision Flow Chart</i> |
| <i>APPENDIX B</i> | <i>Indoor Air Building Survey and Sampling Form</i> |
| <i>APPENDIX C</i> | <i>Instructions for Occupants - Indoor Air Sampling Events (English and Spanish)</i> |
| <i>APPENDIX D</i> | <i>Evaluating Indoor Air Near VOC Contaminated Site fact sheet</i> |
| <i>APPENDIX E</i> | <i>Subsurface Depressurization Systems fact sheet</i> |
| <i>APPENDIX F</i> | <i>Background Volatile Levels in Homes: Literature Review</i> |
| <i>APPENDIX G</i> | <i>Derivation of the Generic Screening Levels</i> |
| <i>APPENDIX H</i> | <i>Common Household Sources of Background Indoor Air Contamination</i> |
| <i>APPENDIX I</i> | <i>Quality Assurance Requirements</i> |

ABBREVIATION LIST

| | |
|-------|---|
| ATSDR | Agency for Toxic Substances and Disease Registry |
| BAQE | Bureau of Air Quality Evaluation |
| BFB | 4-bromofluorobenzene |
| BTEX | benzene, toluene, ethylbenzene and xylenes |
| bwt | below the water table |
| cc | cubic centimeter |
| CHC | chlorinated hydrocarbon |
| CPSi | cancer potency slope, inhalation |
| CRM | certified reference material |
| CSM | conceptual site model |
| DDE | dichlorodiphenyldichloroethylene |
| DNAPL | dense non-aqueous phase liquid |
| DSRT | Division of Science Research and Technology (NJDEP) |
| EDSA | Electronic Data Submission Application |
| FID | flame ionization detector |
| FSPM | Field Sampling Procedures Manual |
| FTDS | field test data sheets (for Analytical Methods TO-15 and TO-17) |
| GC | gas chromatography |
| GC/MS | gas chromatography/mass spectrometry |
| GIS | Geological Information System |
| GWSL | Ground Water Screening Level |
| GWQS | Ground Water Quality Standards |
| HDNL | Health Department Notification Level |
| Hg | mercury |
| HQ | hazard quotient |
| HVAC | heating, ventilation and air conditioning |
| IA | indoor air |
| IASL | Indoor Air Screening Level |

| | |
|-------------------|---|
| ID | inner diameter |
| IEC | immediate environmental concern |
| IRIS | Integrated Risk Information System |
| IRM | interim remedial measure |
| ITRC | Interstate Technology and Regulatory Council |
| J&E | Johnson and Ettinger model |
| Koc | organic carbon partition coefficient |
| LCS | laboratory control samples |
| LFPS | low-flow purging and sampling |
| LNAPL | light non-aqueous phase liquid |
| MDL | method detection limit |
| MIBK | 4-methyl-2-pentanone |
| MW | monitor well |
| µg/m ³ | microgram per cubic meter |
| MTBE | methyl tertiary-butyl ether |
| NAPL | non-aqueous phase liquid |
| NELAP | National Environmental Laboratory Accreditation Program |
| N.J.A.C. | New Jersey Administrative Code |
| NJDHSS | New Jersey Department of Health and Senior Services |
| NJDEP | New Jersey Department of Environmental Protection |
| OD | outer diameter |
| OQA | Office of Quality Assurance (NJDEP) |
| OSHA | Occupational Safety and Health Administration |
| PA DEP | Pennsylvania Department of Environmental Protection |
| PA/SI | Preliminary Assessment and Site Investigation |
| ppbv | parts per billion by volume |
| PCE | tetrachloroethene (also called perchloroethene) |
| PDBS | passive diffusion bag samplers |
| PEL | permissible exposure limit |
| PID | photoionization detector |
| QA/QC | quality assurance/quality control |

| | |
|--------|--|
| RAL | Rapid Action Level |
| RAW | Remedial Action Workplan |
| RBC | risk based concentration |
| RfC | reference concentration |
| RfD | reference dose |
| RfDi | reference dose, inhalation |
| RL | reporting limits |
| RRT | relative retention time |
| SCAN | continuous scanning mode |
| SDG | sample delivery group |
| SGSL | Soil Gas Screening Level |
| SIM | selective ion monitoring |
| SOP | Standard Operating Procedures |
| SRM | standard reference material |
| SSURGO | Soil Survey Geographic Database |
| SSV | safe sampling volume |
| TBA | tertiary butyl alcohol |
| TCE | trichloroethene |
| TRSR | Technical Requirements for Site Remediation (N.J.A.C. 7:26E) |
| URF | unit risk factor |
| USDA | United States Department of Agriculture |
| USEPA | United States Environmental Protection Agency |
| USGS | United States Geological Survey |
| VI | vapor intrusion |
| VOC | volatile organic compound(s) |

1.0 INTRODUCTION

Vapor intrusion (VI) has received increased attention and evolved rapidly over the last few years as a potential exposure pathway of concern in the investigation and remediation of contaminated sites. VI is defined as the migration of volatile chemicals from the subsurface into overlying buildings (USEPA 2002b). The presence of volatile organic compounds (VOC) in soil or ground water offers the potential for chemical vapors to migrate through subsurface soils and along preferential pathways (such as underground utility lines) potentially impacting the indoor air quality of affected buildings.

The accumulation of volatile vapors in impacted structures can result in more immediate health concerns associated with high levels of contaminants, as well as the potential for chronic (i.e., long term) health effects associated with lower levels of site related contaminants. This document addresses both chronic effects and more immediate health concerns.

The objective of the NJDEP document is to provide guidance in determining whether VI of site related contaminants is occurring and to highlight what actions are appropriate. This document replaces the New Jersey Department of Environmental Protection's Indoor Air Sampling Guide for Volatile Organic Compounds (NJDEP 1999).

1.1 Regulatory Basis for the Guidance

The regulatory basis for the evaluation of the VI pathway is rooted in various sections of the Department's Technical Requirements for Site Remediation (NJDEP 2003a), or TRSR. The TRSR (N.J.A.C. 7:26E-1.11) state that the first priority during remediation is to ensure that "contaminants in all media should be contained and/or stabilized to prevent contaminant exposure to receptors and to prevent further movement of contaminants through any pathway." N.J.A.C. 7:26E-1.13 sets forth narrative ground water remediation standards for contaminated sites which "Ensure no release of contaminants to the ground surface, structures or air in concentrations that pose a threat to human health."

Many of the other narrative ground water remediation standards in N.J.A.C. 7:26E-1.13 are also relevant to the VI pathway, including the policies and narrative criteria from the Ground Water Quality Standards (GWQS), in N.J.A.C. 7:9-1.2 and 1.7. These requirements incorporate human health and welfare concerns specified in the November 13, 1991 Basis and Background for the GWQS.

In addition to the above, the TRSR at N.J.A.C. 7:26E-3.5 stipulate that "the site investigation of building interiors shall be conducted when contaminants . . . outside the building have the potential to migrate into the building." The TRSR at N.J.A.C. 7:26E-4.1 also state that the purpose of a remedial investigation is to "identify the migration paths and actual or potential receptors of contaminants on or through air, soil, bedrock, sediment, ground water, surface water and structures at a contaminated site."

Furthermore, N.J.A.C. 7:26E-4.4(h)3viii specifies that the occurrence of ground water contamination above the applicable remediation standards must include evaluation of "any subsurface utilities, basements or other structures to determine whether vapor hazards as a result of the ground water contamination may exist for receptors associated with the utility or structure." The TRSR at N.J.A.C. 7:26E-6.3(d)7 also stipulate that the submission of a proposal for natural ground water remediation must demonstrate that "contaminant levels in ground water do not present a vapor risk to any receptors."

1.2 Intended Use of the Guidance

The NJDEP guidance is intended for use in the evaluation of the VI pathway at primarily VOC contaminated sites located within the state of New Jersey. While this document concentrates on VOC contaminated sites, the Department may investigate other volatile compounds for the VI pathway on a case by case basis. The potential for VI impacts shall be evaluated if volatile contaminated media are present at a site. In addition, this evaluation shall be considered for sites where active ground water and/or soil remediation systems are proposed or being undertaken that may affect soil vapor concentrations and the generation of potentially volatile/toxic degradation products with the potential to impact the air quality of nearby structures. These systems include, but are not limited to, air sparging, bioremediation, bioventing and chemical oxidation systems.

The intended use of this document is to assist interested parties in determining whether VI impacts may be present that require additional actions to mitigate or eliminate actual or potential human health impacts. This guidance addresses those procedures currently recommended by the New Jersey Department of Environmental Protection (NJDEP or the Department) in the evaluation of potential VI related impacts at a site. While this document is guidance, not regulation, evaluation and remediation for the VI pathway is required as part of the TRSR (as previously discussed). It is therefore recommended that the regulated community consult with the Department before implementing methodologies/procedures not included in this document.

1.3 Overview of the Guidance

This guidance incorporates a risk based, staged approach to evaluate the potential for VI at sites under review. The document has been developed after consideration of the latest, state of the science procedures/methodologies currently included in USEPA and other State guidance, as well as information available from conferences and training events, that address the VI pathway. While the Department has incorporated many of the latest recommended methodologies in the document, New Jersey specific characteristics, input parameters and policies have also been included, where applicable.

The Department's investigative strategy for the VI pathway consists of a series of stages designed to consistently and logically progress through the process of assessing the potential for VI. These stages are structured to be consistent with the organization of a typical investigation as required in the TRSR. Further detail on these stages can be found throughout this document. In addition, the Decision Flow Chart (Appendix A) should be consulted when assessing the VI pathway.

Chapter 2 provides a detailed introduction to concepts relevant to the VI pathway and guidance on developing a conceptual site model (CSM).

Chapter 3 describes the general decision framework for the phased approach the Department has defined for the evaluation of a site. The Preliminary Assessment and Site Investigation phase presents a series of situations where prompt action is necessary in order to address potential impacts to public health. The Remedial Investigation phase deals with strategies for

investigating and assessing the VI pathway. Site-specific screening options and procedures are included in this phase. Finally, the Remediation and Monitoring phase addresses remedial actions, monitoring and maintenance at the site.

The generic screening levels and their application are discussed in Chapter 4. Chapter 5 covers the site-specific screening options available for use in the evaluation of a site. Recommended investigative procedures for ground water, soil gas and/or indoor air are presented in Chapter 6. Chapter 7 discusses the evaluation of analytical data collected to address the pathway.

Consideration of background ambient air and indoor air quality in the evaluation of a site is discussed in Chapter 8. Chapter 9 includes current guidance on addressing sites contaminated with petroleum hydrocarbons. Remedial alternatives along with monitoring and institutional control requirements are covered in Chapter 10. Chapter 11 contains guidance on community outreach when evaluating potential VI impacted sites. The tables and appendices included in the

VI Pathway Investigative Strategy

Preliminary Assessment and Site Investigation

- Stage 1 Assess potential for vapor intrusion
- Stage 2 Rapid Action Determination
- Stage 3 Evaluate existing data against screening levels

Remedial Investigation

- Stage 4 Develop and implement VI Investigation Workplan
 - 4A. Delineate GW contamination
 - 4B. Investigate soil gas
 - 4C. Conduct sub-slab and indoor air sampling
- Stage 5 Evaluate RI data using generic screening levels
- Stage 6 Prepare and implement site-specific investigation
- Stage 7 Evaluate data using generic or site-specific screening levels

Remediation and Monitoring

- Stage 8 Determine appropriate remedial action
- Stage 9 Implement remedial action
- Stage 10 Establish a long-term monitoring program
- Stage 11 Assess ability to terminate remedial action

guidance are listed in the Table of Contents and provide detailed information in support of the various topics included in the document.

1.4 Guidance Updates

As previously noted, evaluation of the VI pathway is a rapidly evolving field. With this knowledge, the Department will update the document as the state of the science advances. The Department intends to modify the screening level tables twice a year based on updates to the USEPA Region III Risk Based Concentration (RBC) Table used in the development of the screening levels. The Department will also modify the guidance as appropriate based on advances in the recommended methodologies, analytical procedures and associated analytical reporting limits.

The current document along with updates to the screening levels and other sections of the document are, or will be, presented on the Department's web site at www.state.nj.us/dep/srp/guidance/vaporintrusion/. It is recommended that interested parties refer to the NJDEP web site to ensure that they are using the most current information in the evaluation of a site.

2.0 CONCEPTUAL SITE MODEL

Assessing the potential for VI to indoor air should begin with visualizing a simplified version of the site or physical setting; this simplified idea, picture, or description is a conceptual site model (CSM). This chapter serves as a guide for developing a CSM and also as a detailed introduction to the VI pathway. Although not required, NJDEP strongly recommends early development of a written, illustrated CSM that can be used to plan, scope, and communicate the next steps in the investigation and any remedial actions, if needed. Starting an investigation in the absence of a CSM is likely to increase costs and decrease efficiency. The CSM should be updated and refined, as new data become available.

The basic components of a CSM are known or suspected contaminant sources, contaminant migration pathways, potential human receptors and the exposure routes by which these receptors may come in contact with contaminants on a site-specific basis. Figure 2-1 below is an illustration of a simple, preliminary CSM for the VI pathway.

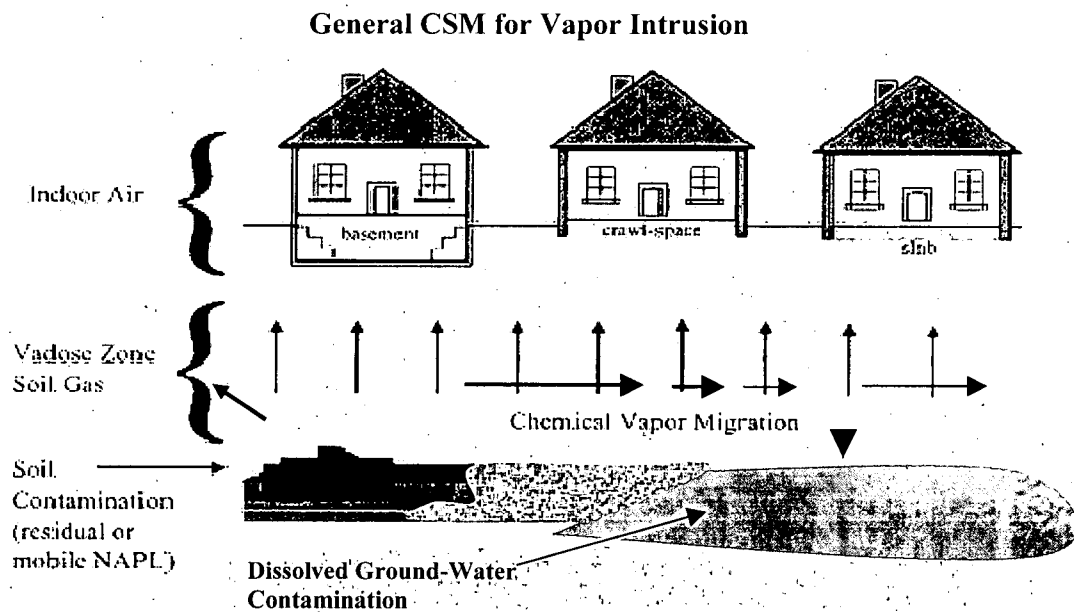


Figure 2-1. General Vapor Intrusion Conceptual Model

Source: USEPA 2002b

The CSM serves to identify currently complete or potentially complete pathways to receptors and the potential for future risks. There is always some degree of uncertainty in estimating

current or future exposures, and the CSM should explicitly address uncertainty, often through consideration of “worst-case” and “best estimate” scenarios. If neither scenario poses any unacceptable risks or both scenarios pose unacceptable risks, it may not be necessary to reduce uncertainty through further investigation or analysis prior to implementing corrective measures or concluding the pathway poses no unacceptable risk. Otherwise, additional information may be needed to reduce uncertainty to a level where current and future risks can then be characterized and addressed, as needed. The CSM, therefore, can be an effective tool for investigation and risk management decisions, functioning to streamline those pathways that need to be addressed and those that do not.

Figures, maps, cross sections, diagrams/flow charts, tables and graphs can be used to summarize and illustrate the overall CSM, its various components, and the associated data. These visual aids are more effective tools than text descriptions alone for communicating complex information to interested parties. The narrative should clarify which CSM components are site-specific, measured or known, and which include assumptions or general information.

Investigators (i.e., person(s) responsible for evaluating the VI pathway) should start a CSM by incorporating all relevant site-specific data, historical information, and relevant general concepts/information. Relevant off site and regional information (e.g., aerial photographs, Geographic Information System data, historical and current tax maps, etc.) should also be incorporated.

As new data are collected, it is vital to compare them with the current CSM and modify the CSM as needed by incorporating the new information. The accuracy of the CSM can be evaluated by the degree to which new information is consistent with expectations based on the CSM prior to the data collection.

A CSM is not a mathematical model, but can be the basis for a mathematical model. This chapter focuses on the conceptual framework, which must be developed before any mathematical representation or modeling is attempted. The following subsections describe the components of the CSM in detail:

- Sources of VI
- Vapor Migration Mechanisms
- Receptors and
- Factors Affecting Vapor Migration.

2.1 Sources of Vapor Intrusion

Initial consideration in the preparation of a CSM should be centered on whether there is a vapor source with the potential to cause VI. In general, a vapor source of VI can be defined as the presence, or reasonably suspected presence, of a chemical of sufficient volatility and toxicity in the subsurface with sufficient mass and/or concentrations to pose a possible inhalation risk within current or future occupied overlying enclosures. This definition includes the presence of a volatile chemical or chemicals adsorbed to, or in the pore space/fractures of unsaturated soil or rock, or in the uppermost portions of the saturated zone. Such vapor sources can exist in the form of: free phase or residual NAPL above or near the top of the saturated zone; contaminated soil in the vadose zone; and shallow dissolved phase contamination in ground water. Another possible source of subsurface VI is the release of volatile compounds in the vapor phase from underground tanks or piping and certain types of aboveground facilities that use volatile compounds during operations. This particular source is commonly referred to as a “vapor cloud.” Sources of indoor air contamination not associated with VI (e.g., ambient air, building materials, consumer products) should also be considered when developing and evaluating a CSM.

2.2 Vapor Migration Mechanisms

When a chemical of sufficient volatility and toxicity is present in the subsurface, there are several transport mechanisms by which the chemicals can migrate. The CSM should identify the major and minor migration pathways and processes through which a receptor can be exposed at a particular site. The four main transport mechanisms that should be considered are described and illustrated below.

- Diffusion of vapors from sources in the unsaturated zone
- Diffusion of vapors from sources in shallow ground water
- Advective/convective transport of vapors
- Vapor migration through preferential pathways

2.2.1 Diffusion of vapors from sources in the unsaturated zone

Diffusion occurs as a result of a concentration gradient between the source and the surrounding area; it can result in the upward, lateral or downward migration of vapors through the vadose zone. The location of the source is an important factor influencing the direction of vapor migration. Identifying soil gas concentration gradients may help determine the location of unidentified vapor sources. Figure 2-2 illustrates lateral and downward vapor migration in the

Vapor Diffusion

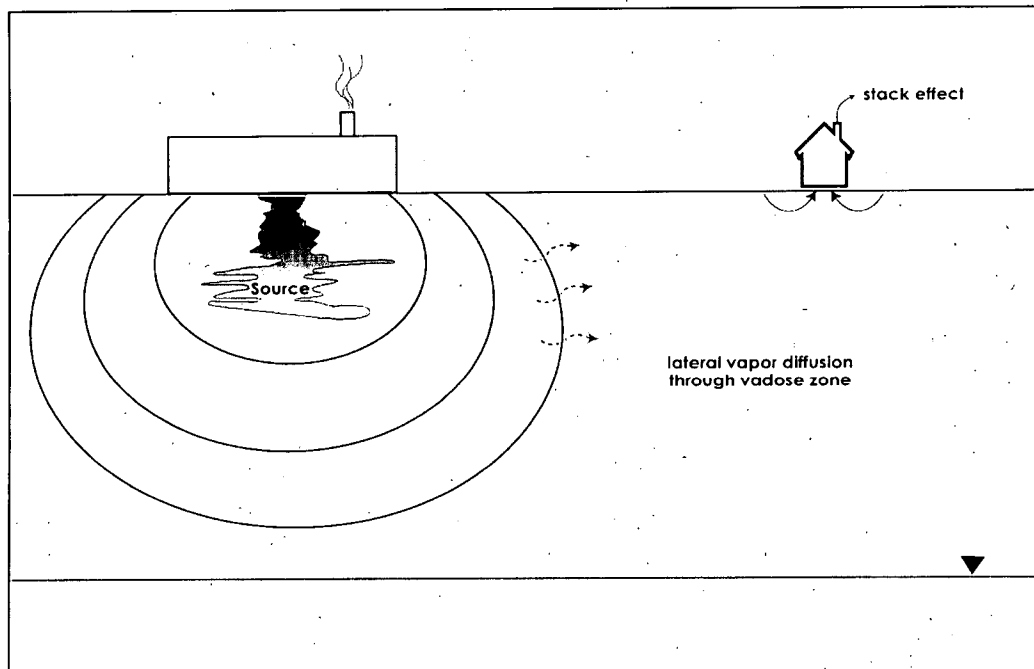


Figure 2-2. Vapor Diffusion from Release at Surface
Source: McAlary 2003

unsaturated zone from a release of contaminants near the surface. The USEPA Draft Vapor Intrusion Guidance (USEPA 2002b) recommends 100 feet as an initial estimate for steady state travel distance based on diffusive vapor transport in the vadose zone. Variability in site characteristics, such as soil porosity, effective permeability, ground surface cover, ambient temperature and age of a release may increase or decrease the distance vapors migrate. A relatively impermeable surface cover above a vapor source for example, may increase the distance a vapor plume would travel laterally if it significantly impedes vapors from escaping to the atmosphere.

2.2.2 Diffusion of vapors from sources in shallow ground water

Diffusion occurs as a result of a concentration gradient between the source and the surrounding area; in this case, the source is shallow groundwater contamination and/or NAPL. This can result in the upward or lateral migration of vapors through the vadose zone. Figure 2-3 illustrates diffusion of vapors in the vadose zone from shallow ground water contamination. Depending on the hydraulic conductivity, hydraulic gradient, aquifer heterogeneity, time since chemicals were released and natural attenuation processes, the distribution of volatile chemicals in ground water may extend considerable distances.

Within a set volumetric space where contaminated ground water is the only source of vapors in the subsurface, the total mass of volatiles off-gassing from ground water and diffusing through the vadose zone (vertical mass flux) cannot exceed the total mass of volatiles moving through that space laterally in ground water. For aquifers with slower ground water velocity, the lateral mass flux in shallow ground water leaving the source area may be the limiting factor in VI impacts.

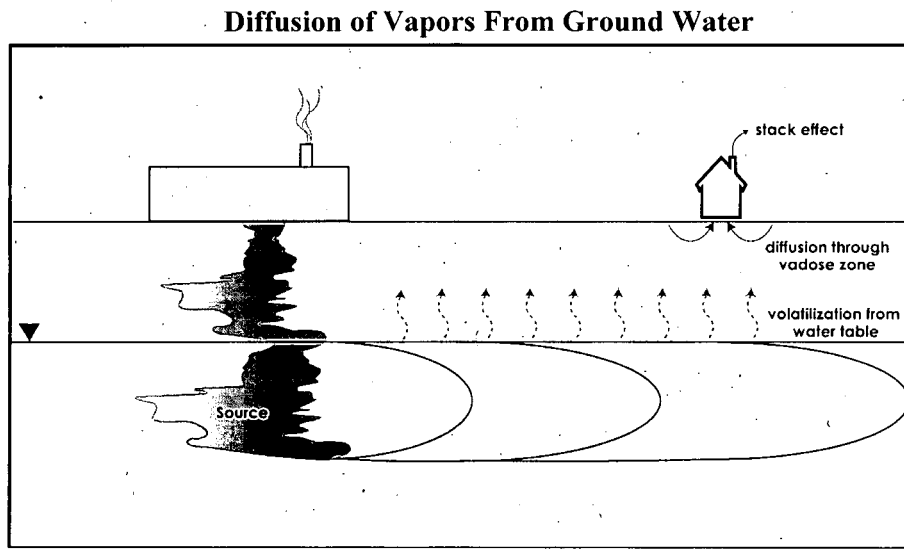


Figure 2-3. Vapors Diffusing toward Buildings from Shallow Ground Water

Source: McAlary 2003

2.2.3 Advective/convective transport of vapors

The horizontal and vertical movement of vapors located near a building foundation is often affected within an area referred to as the “zone of influence” (see Figure 2-4). Chemicals entering this zone are drawn into the building via soil gas advection and convection resulting from building interiors that exhibit a negative pressure relative to the outdoors and the surrounding soil. The reasons for this pressure differential include: 1) factors relating to operation of HVAC system including inadequate combustion or makeup air and unbalanced air supply and exhaust systems; 2) the use of fireplaces and other combustion sources, which results in venting of exhaust gases to the exterior; 3) the use of exhaust fans in bathrooms and kitchens; 4) higher temperatures indoors relative to outdoors during the heating season or as a result of solar radiation on rooftops; and 5) pressure exerted on the wall of a building caused by wind movement over the building (Bernoulli’s principle). The combination of these actions/conditions results in a net convective flow of soil gas from the subsurface through the building foundation to the building interior. As would be expected from the above list, indoor air volatile concentrations are generally higher during the heating season in homes affected by VI.

Advective/Convective Transport of Vapors

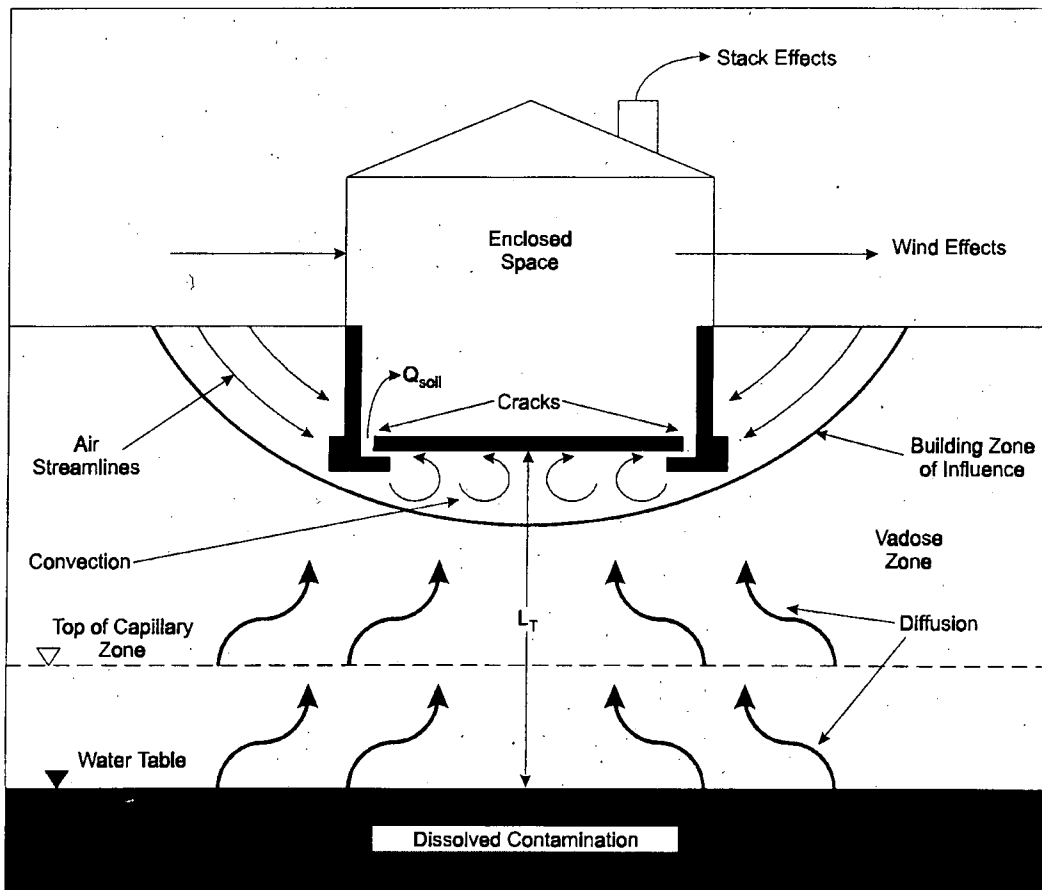


Figure 2-4. Advective and Convective Transport Near Buildings

Source: USEPA 2004d

Figure 2-4 illustrates the transport of vapors near a typical residence or building with a basement. The rate of contaminant entry through the foundation and the air exchange rate of the building will determine the concentration of the contaminants in the home resulting from VI. A similar pattern of soil gas movement can occur around buildings without a basement or around those without any concrete foundation slab. The term Q_{soil} in Figure 2-4 represents the rate of soil gas entry into the building. In many cases, granular fill materials are placed beneath concrete slabs or adjacent to building footings, which may be much more permeable to air flow than surrounding soils. Air flow will occur through the path of least resistance, so the streamlines for air flow may be different than those depicted on Figure 2-4.

Advective/convective transport of vapors can occur in other scenarios. It has been observed that certain commercial and business operations may result in volatile organic vapors entering the unsaturated zone solely as a vapor possibly due to density differences between these vapors and the atmosphere (USEPA 2002b; Hartman 1998). These operations could include tetrachloroethene (PCE) dry cleaning units, vapor degreasers in machine shops, spray booths in inking or painting facilities using chlorinated solvent based inks or paints, and USTs/underground piping. Highly permeable deposits and very high vapor concentrations are necessary for there to be significant density dependent transport below ground, therefore this scenario is likely to be relatively rare. Contaminated soil vapor may also occasionally result from pressurized buildings forcing contaminated indoor air out through openings in the foundation and into nearby soil. The affected area or zone of influence would likely be relatively small, but could affect sub-slab or other soil gas samples collected below buildings or structures such as those described above.

Another possible advective vapor transport mechanism, called “barometric pumping,” is caused by cyclic changes in atmospheric pressure. These changes create a “piston like” force on soil gas, possibly causing a cyclic up and down flow of contaminant vapors in the affected interval. The magnitude of a barometric pressure cycle is typically a small percentage of atmospheric pressure and its effect decreases with depth. The soil texture, soil air permeability, and moisture content affect the depth to which the pressure change may affect vapor transport. Soil gas compression and expansion in response to barometric pressure fluctuations may alternately enhance or inhibit VI.

In areas subject to tidal fluctuation in the water table, or rapid increases in the water table elevation due to stormwater runoff, such increases in water table elevation may enhance advective transport.

2.2.4 Vapor migration through preferential pathways

In preparation of each CSM, investigators may look for the presence and locations of natural and man made pathways in the subsurface with high gas permeability through which vapors can rapidly migrate. The term preferential exposure pathway has been defined, in part, as:

“...a natural (e.g., shallow rock or vertically fractured soil) or manmade (e.g., buried utilities) feature that creates a sufficiently direct pathway from a source to a receptor to make the use of the default model [the Johnson and Ettinger model] for predicting indoor air concentrations unacceptable. Shallow utilities buried at a depth that is insignificant with respect to the column of soil between the slab and the source do not automatically constitute a preferential pathway, nor should this definition include surface paving outside the building or the presence of crushed stone beneath the slab as normally placed for slab foundation material.” (PA DEP 2004)

Naturally occurring fractures and macropores may facilitate vertical or horizontal vapor migration while anthropogenic features such as utility conduits would likely facilitate horizontal vapor migration due to their shallow depth (USEPA 2002b). Buildings that are, or may become, inhabited should be evaluated if they are associated with a preferential pathway that is within some reasonable distance of a source area (based on professional judgment).

Investigators should also evaluate the potential for VI in situations where a preferential pathway leading to a structure runs near to, or through, a source area. For sources containing aerobically degradable contaminants, however, it is unlikely that sufficient vapors will reach the structure to result in a VI problem unless the pathway and structure are both very close to the vapor source. Biodegradation of benzene, toluene, ethylbenzene, and xylene (BTEX) vapors in the vadose zone has been shown to be a very efficient process as long as sufficient oxygen is available (DeVaull, et.al. 1997). Thus, if a preferential pathway is not close to a source area, biodegradable vapors would likely degrade before reaching the pathway and/or within the pathway before reaching the structure.

2.3 Receptors

The Technical Requirements for Site Remediation (NJDEP 2003a) define a receptor as “any human or other ecological component which is or may be affected by a contaminant from a contaminated site.” The primary VI receptors are the human occupants of enclosed spaces overlying subsurface volatile contamination. Exposure to volatiles can result in health problems in individuals occupying a building subject to VI. Enclosed spaces or buildings, for the purpose of this guidance, are defined as any structure currently or potentially impacted by subsurface volatile contaminants. To account for possible change in future use, VI is of potential concern in buildings/enclosed spaces whether or not they are currently occupied. Buildings with significant air exchange rates (e.g., commercial garages/spaces with large doors/openings) or significantly limited use (e.g., small utility sheds) will be evaluated on a site-specific basis.

Human exposure typically can take place under a residential (unrestricted use) or nonresidential (restricted use) exposure scenario. Residential settings include single family homes, townhouses, and apartment buildings. Receptors under a residential exposure scenario consist of both adults and children who are expected to spend a greater period of time in a residential setting than those individuals in a nonresidential setting. As discussed in Chapter 4, it is the Department’s policy that day care centers and schools are evaluated as a residential use due to the potentially sensitive nature of the exposed population (children).

Nonresidential settings include office buildings and commercial or industrial complexes. Nonresidential receptors consist of adult workers in the above buildings or complexes. Nonresidential settings with sensitive populations (e.g., working pregnant women) will be handled on a site-specific basis. Occupational settings that fall under the purview of OSHA may be handled differently than those not subject to OSHA regulations when indoor air concentrations from normal operating practices can not be ruled out.

2.4 Factors Affecting Vapor Migration

Vapor and liquid transport processes and their interactions with various geologic and physical site settings (building construction and design) under given meteorological conditions have

unique effects on the VI pathway. Variations in building design, construction, use, and maintenance, site-specific stratigraphy, sub-slab composition and temporal variation in atmospheric pressure, temperature, precipitation, infiltration, soil moisture, water table elevation, and other factors, combine to create a complex and dynamic system. General aspects of several of these processes and site settings/conditions are described and illustrated below. These factors are not listed in a prioritized manner and not all factors are relevant at every site:

- Biodegradation (of volatile contaminants as they migrate in the vadose zone)
- Site Stratigraphy
- Soil Moisture and Ground Water Recharge
- Fluctuations in Water Table Elevation
- Ventilation Systems in Commercial/Industrial Buildings.

2.4.1 Biodegradation

Many volatile contaminants, especially nonchlorinated hydrocarbons, can be degraded by indigenous soil microbes in the presence of oxygen. Oxygen is ubiquitous in the atmosphere, at a concentration of about 21%, which constitutes an essentially limitless supply. Oxygen is transported to the subsurface by barometric pumping, and by diffusion if there is a concentration gradient, which will develop at sites where oxygen is being consumed in the subsurface at appreciable rates. In some cases, oxygen is consumed at rates faster than it migrates downward, so degradation rates vary significantly from site to site (Roggemans et al. 2001).

2.4.2 Site Stratigraphy

Figure 2-5 illustrates a hypothetical example of how determining site stratigraphy can be crucial to discovering actual or potential vapor migration pathways. Figure 2-5 depicts a geologic layer of low permeability that is both dipping toward a nearby building and creating a perched water table. Perched, saturated zones are often very localized and only intermittently present. As shown in Figure 2-5, a local perched zone may also occur where there is a leak in a water supply or sewer line. The direction of dip shown in Figure 2-5 is causing contaminated ground water in the perched zone to move in the opposite direction from the regional water table. This situation creates the potential for VI in a location that would not be expected, based solely on

determination of the regional ground water flow direction. Conversely, a low permeability layer in the unsaturated zone can impose significant impedance to upward migration of vapors from an underlying source (e.g., ground water), and prevent unacceptable VI in areas where it might otherwise occur. The second scenario is probably more common but, in either case, some understanding of the stratigraphy is necessary to develop an appropriate CSM.

Performing investigative work to evaluate natural and manmade stratigraphy (e.g., boring logs, surface geophysics) could also reveal features such as a highly permeable gravel layer or a dry, fractured clay layer. Both types of layers could result in increased vapor migration rates, and/or distances, possibly as far as a few hundred feet from a source area (McAlary 2003; USEPA 2002b). Not including such stratigraphic features in a CSM could negatively affect the selection of appropriate sampling methods, or locations.

Perched Water Transport

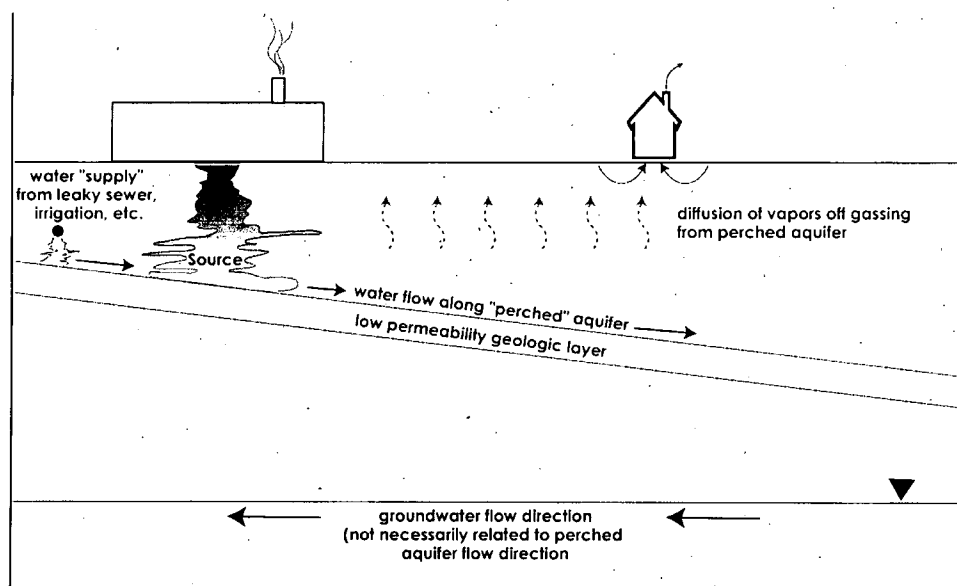


Figure 2-5. Low Permeability Layer Affecting Vapor Migration

Source: McAlary 2003

2.4.3 Soil Moisture and Ground Water Recharge

The rate of vapor diffusion is about 10,000 times that of diffusion of dissolved contaminants through water. Thus, high soil moisture levels in the vadose zone can dramatically reduce the effective rate of vapor migration through soil. The possible impact of high soil moisture should be considered in the development of the VI investigation workplan. More specific information on how these changes could affect investigative approaches is discussed in Chapters 4 and 6.

In many areas of New Jersey, aquifer recharge is likely to play a significant role in vapor migration. In the Coastal Plain Physiographic Province, and wherever the surficial saturated layer occurs in unconsolidated sediments and deposits with a ground water flow regime that is relatively homogeneous and isotropic, infiltrating precipitation and irrigation can often influence the vertical migration of a ground water contaminant plume. As such, it is important to assess the actual or potential degree of site-specific infiltration. Factors such as the relative amount of precipitation in a given period of time, type of surface cover, extent of lawn watering, and soil permeability should be evaluated.

As ground water moves away from the source area, infiltrating water that reaches the water table will lie on top of the contaminated ground water and, gradually, a lens of clean ground water may form above a contaminant plume (Figure 2-6). The probability of this occurrence, and the thickness of the lens, would increase as the plume moves further away from the source, especially in areas where precipitation can rapidly infiltrate and/or a downward hydraulic gradient exists due to other factors.

An NJDEP Site Remediation Program May 2001 newsletter article, entitled "Diving Plumes that Migrate to Depths Below the Water Table," (Griesemer 2001) is available at www.state.nj.us/dep/srp/news/2001/0105_04.htm. The article describes this phenomenon and various causes for a "diving plume."

Clean Water Lens Impeding Diffusion to Vadose Zone

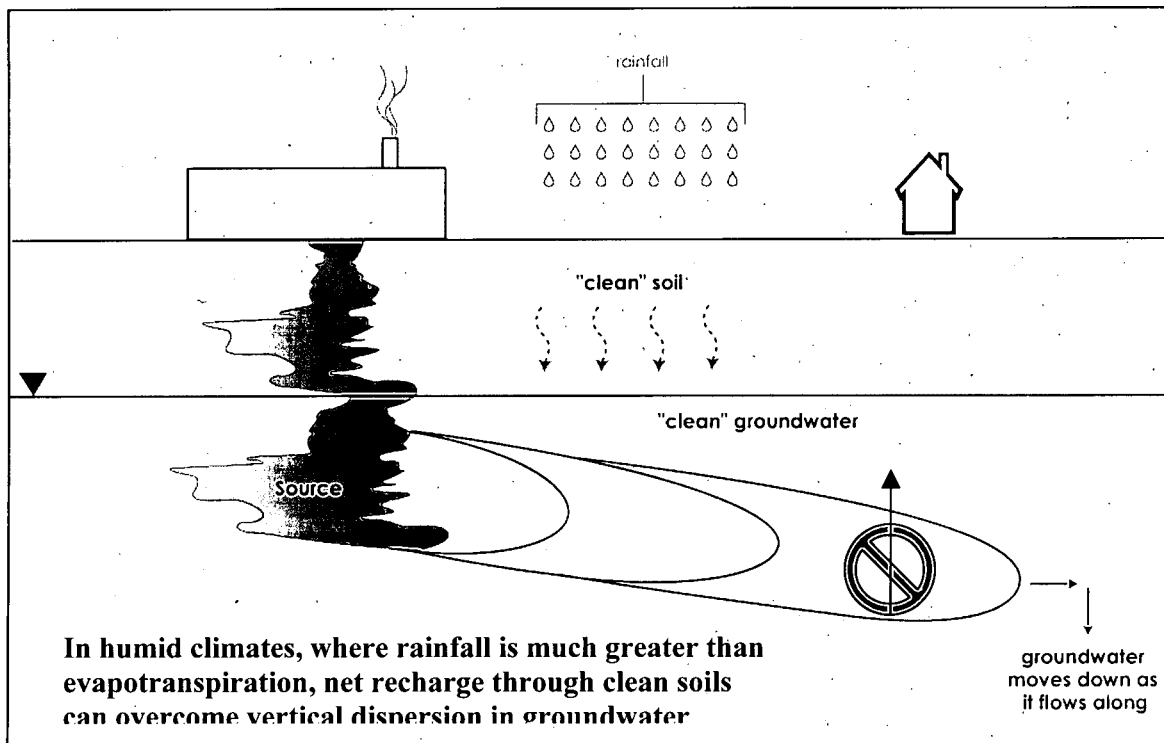


Figure 2-6. Clean water Lens Impeding Diffusion to Vadose Zone

Source: McAlary 2003

Because the rate of diffusion of contaminants through the overlying clean ground water is so slow, the overlying ground water can greatly impede or prevent volatiles in deeper ground water from reaching the unsaturated zone, thus possibly preventing a vapor intrusion situation (Fitzpatrick and Fitzgerald 2002; McAlary et al. 2004).

2.4.4 Fluctuations in Water Table Elevation

Even where a clean water lens has been created as described above, changes in the elevation of the static water level may affect whether VI occurs. A significant drop in water table elevation (e.g., during a prolonged drought) can expose an area of contaminated ground water previously separated from the vadose zone by a clean water lens resulting in a potential VI situation.

Falling Water Table

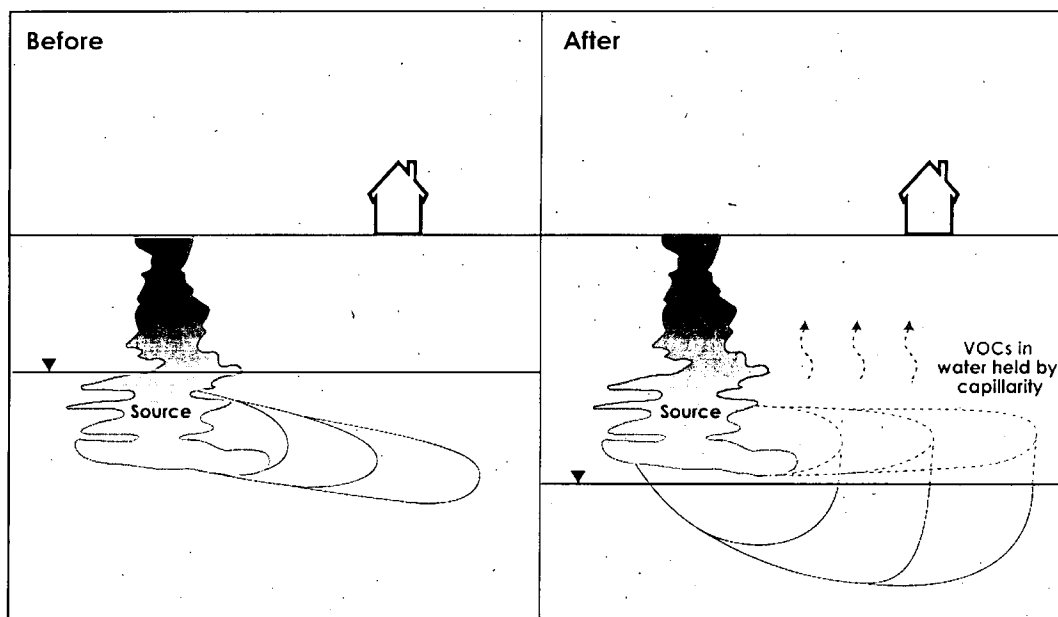


Figure 2-7. Falling Water Table Exposes Dissolved Plume to Vadose Zone

Source: McAlary 2003

If seasonal water table fluctuations are small relative to the thickness of the clean water lens, then off gassing will be impeded. Where the lens is thin (2 to 3 feet) even normal water level changes may result in the vertical movement of volatiles as depicted in Figure 2-7. This situation increases the contaminated surface area where diffusion into the unsaturated zone can occur. Some of those vapors may migrate far enough to cause VI into buildings and some can move into and above the depth interval where the clean water lens previously existed and subsequently partition back into the dissolved phase, contaminating capillary water and fresh recharge water (Mendoza and McAlary 1990). Water table fluctuations may result in short term variation in volatilization to the vadose zone over a few weeks to months. This variation could affect indoor air concentrations where the pathway is already complete or change whether VI occurs. These phenomena can have important implications for appropriate ground water sampling procedures and for when soil vapor sampling is important.

Figure 2-8 illustrates a situation where NAPL reaches the capillary fringe and/or soil is contaminated with residual NAPL in the zone surrounding the capillary fringe. Fluctuations in the water table could smear the product vertically and greatly enhance the phase transfer “vertical mixing” between vapor and dissolved contamination discussed in the previous

paragraph. As the plume moves in the downgradient direction, these processes would result in much higher volatile concentrations near the water table than in deeper intervals not within the zone of fluctuation. Vapors would be likely to migrate much further in this scenario than one where NAPL and high levels of contaminants do not reach the moist transition zone just above the capillary fringe. This phenomenon has been called an interface zone ground water plume, with the interface zone being defined “to include the upper ground water zone in close proximity to the water table, the fully saturated capillary fringe and the transition zone to residual water saturation” (Rivett 1995).

Water Table Fluctuations

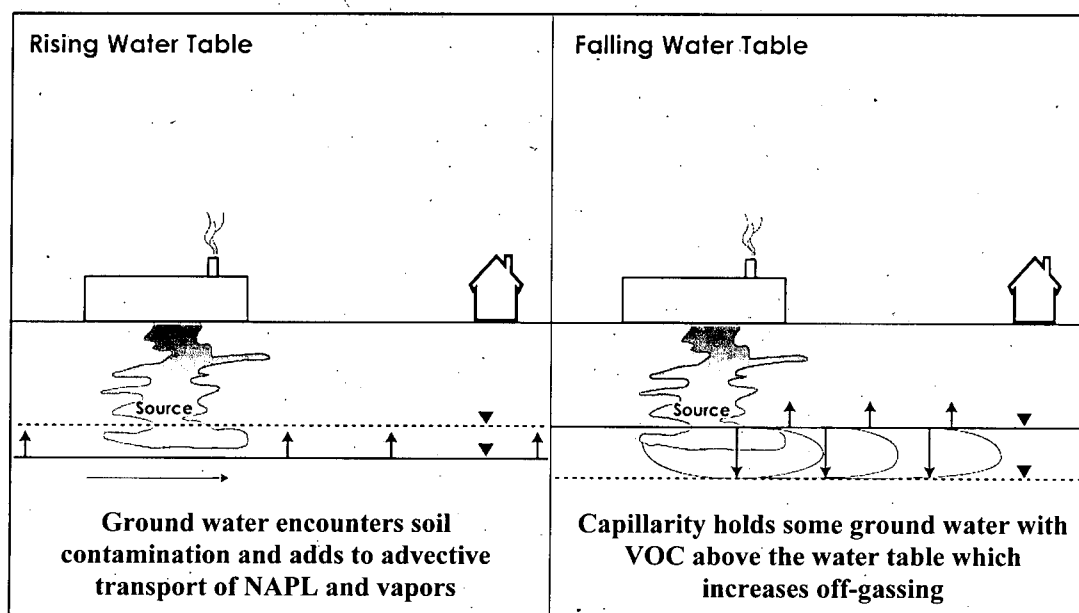


Figure 2-8. Fluctuations in Water Table Create Interface Zone Vapor Plume

Source: McAlary 2003

2.4.5 Ventilation Systems in Commercial/Industrial Buildings

Commercial and industrial buildings often are designed with higher air exchange rates than residential structures, which may reduce the potential for VI. However, heating, ventilating and air conditioning (HVAC) systems in these buildings may intentionally, or inadvertently, result in either building depressurization or positive indoor air pressure relative to outdoors. Also, a mix

of these two situations may occur depending on location within the building. Different floors of multistory buildings may exhibit different pressure readings (e.g., negative pressure on lower floors and positive pressure on upper floors). Therefore, prediction of potential soil gas entry rates into these buildings would generally require site-specific assessment.

The actual case example depicted in Figure 2-9 shows a subsurface vadose zone source of VOC immediately adjacent to an industrial building. VI was not occurring at this site and no

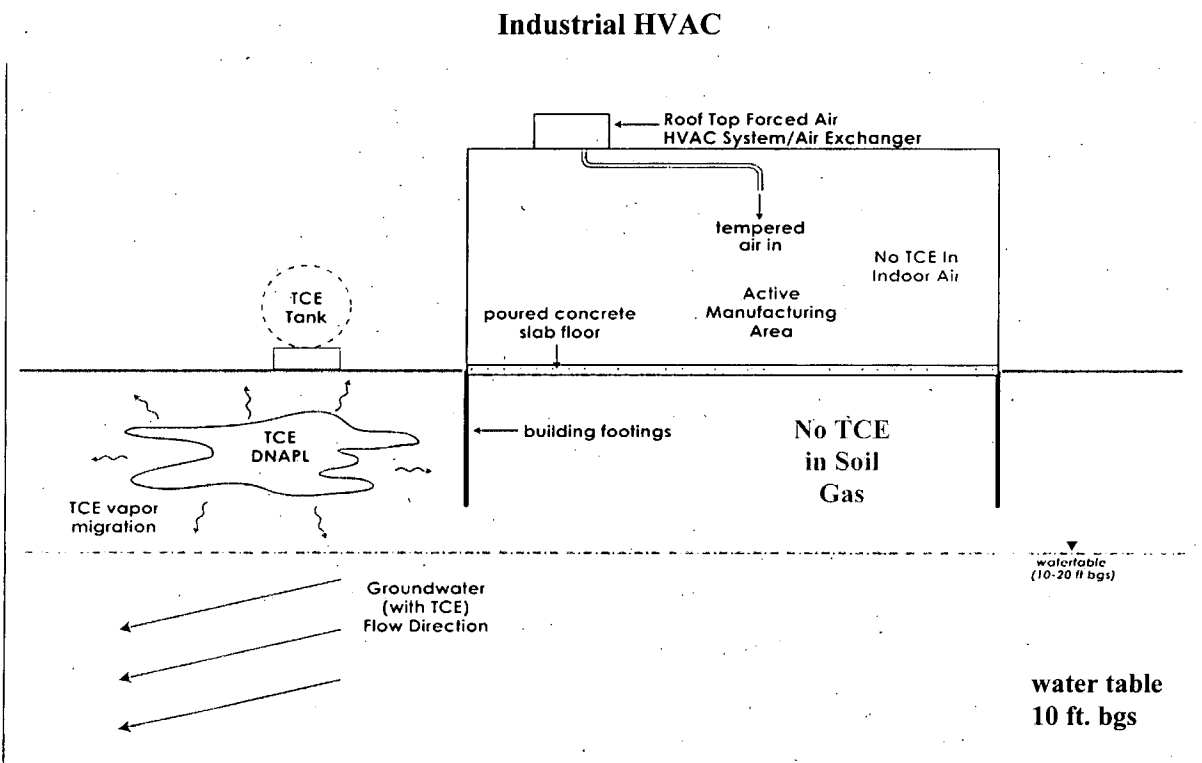


Figure 2-9. Industrial HVAC Preventing Vapor Intrusion

Source: McAlary 2003

significant trichloroethene (TCE) vapors were detected in soil gas immediately below the building. Contaminated ground water was moving away from, not under the building. As indicated in Figure 2-9, the HVAC system pumps air into the building, most likely causing it to be positively pressurized (McAlary 2004). Therefore, advective/convective transport of TCE vapors toward the building due to a stack effect around the building was apparently not occurring. Another likely reason that no significant TCE was detected in the soil gas under the

building is that the building footings were installed through most of the vadose zone thickness, inhibiting lateral diffusion of TCE through the vadose zone to the area directly under the building. It may be the combined affect of both the HVAC system and the building's foundation construction that prevented VI in this case.

Other case examples also indicate that commercial and industrial HVAC systems can create a positive air pressure within a building (Berry-Spark et al. 2004), instead of the assumed negative pressure indicated in Figure 2-4. All relevant building characteristics should be investigated and included in the CSM. For commercial buildings, facility engineers can often provide considerable detail on HVAC design and operations.

3.0 DECISION FRAMEWORK

The Decision Flow Chart (Appendix A) is designed to assist the investigator in assessing the appropriate steps when evaluating the VI pathway. The chart was formulated to address most typical situations where suspected indoor air impacts may have occurred due to sources outside the building (e.g., soil or ground water contamination) or known spills inside the building. As always, please consult the NJDEP case manager or technical support personnel for any circumstances that are unique or present complex problems not fitting the paradigm.

The Department has utilized a phased approach to the investigation of the VI pathway. This framework follows the basic provisions of the USEPA's Draft Vapor Intrusion Guidance (2002b) and incorporates both generic and site-specific procedures. Refer to Section 1.3 for further discussion on the phased approach.

The Preliminary Assessment and Site Investigation phase encompasses those circumstances where rapid action may be required. The Remedial Investigation phase employs generic screening levels that can be compared to analytical data from indoor air, sub-slab or near slab soil gas, and ground water samples to resolve whether there is the potential for this pathway to be complete. At this time, generic screening levels for soil sample results have not been developed. Site-specific parameters or alternative sampling approaches can be employed as part of the remedial investigation. The Remediation and Monitoring phase addresses remedial actions and monitoring requirements.

3.1 Preliminary Assessment and Site Investigation

Preliminary Assessment and Site Investigation (PA/SI) consists of three stages - a general assessment of the VI pathway (Stage 1); a determination whether rapid action is warranted at the site (Stage 2), and a comparison of available data to the generic screening levels.

In order for the VI pathway to be complete, there must be a source (principally volatile organic compounds), a potential pathway involving an impacted matrix (e.g., groundwater, soil, and/or

soil gas), and an impacted receptor (current or future) proximal to the source or pathway. Stage 1 involves confirming that one or more contaminants of concern represent a potential risk due to VI. In general, the compounds listed in Table 1 are the principal VI contaminants (although other compounds may be added to the list in the future).

Stage 2 defines a series of situations where VI is likely to require rapid action. This action may be limited to the prompt implementation of a VI investigation. Alternately, the decision may be made that an interim (or emergency) remedial measure is required. These conditions include:

- Known spill in a structure (e.g., heating oil tanks);
- Physiological effects reported by occupants (with a known or suspected source nearby);
- Wet basement or sump with contaminated ground water nearby;
- Odors reported in a structure (with a known or suspected source nearby);
- Free product (as defined in N.J.A.C. 7:26E) at the water table under or immediately adjacent to a structure; and,
- Other short-term safety concerns.

Consistent with the USEPA (2002b), short term safety concerns are “known, or are reasonably suspected to exist, including: a) measured or likely explosive or acutely toxic concentrations of vapors in a building or connected utility conduits, sumps, or other subsurface drains directly connected to the building and b) measured or likely vapor concentrations that may be flammable/combustible, corrosive, or chemically reactive.” For the purposes of Stage 2, odors refer to “chemical” or “solvent” or “gasoline” complaints by occupants.

Professional judgment should be applied to these qualitative criteria when a determination is made to implement a rapid action. The condition in question should be related to an event or observation in or immediately adjacent to the structure in question. As with all indoor air sampling events, the investigator should properly assess the relative impact from background sources on the overall indoor air quality.

The Department has prepared Rapid Action Levels (RAL) in Table 2 that represent trigger levels for the initiation of prompt action at occupied buildings to further investigate the VI pathway and/or minimize impacts to building occupants through the implementation of an interim remedial measure (IRM). The VI investigation can proceed following the mitigation of the RAL exceedance. If a building is currently unoccupied, the rapid pace associated with the RAL is unnecessary. The investigation and/or remedial action can proceed at the normal speed of implementation.

In addition, Health Department Notification Levels (HDNL), developed in consultation with NJDHSS, are also listed in Table 2. These values, when exceeded in occupied buildings, indicate the need for the Department to inform the local and/or state health departments about the site and the associated vapor intrusion related indoor air concentrations for further evaluation and possible emergency actions. On a case by case basis, the health department may also be notified when elevated indoor air levels below the HDNL are present in an occupied school, day care center, health care facility, or other structure with sensitive receptors.

Stage 3 employs generic screening levels to determine whether the VI pathway warrants further investigation and/or remediation based on existing data. The Department has developed these screening values for ground water, indoor air and sub-slab or near slab soil gas. (Refer to Appendix G for further discussion on the development of these screening levels.)

Ground water data should be compared to NJDEP Ground Water Screening Levels (GWSL) in Table 1. When indoor air samples are collected, the results should be compared to the NJDEP Indoor Air Screening Levels (IASL) in Table 1. The NJDEP Soil Gas Screening Levels (SGSL) in Table 1 should be compared to the sub-slab and/or near slab soil gas results. Soil gas data collected from exterior soil gas locations (as distinct from sub-slab or near slab) are generally not appropriate for comparison to the SGSL. Refer to Section 6.3 (Exterior and Near Slab Soil Gas Sampling Procedures) for further discussion on the applicability of exterior soil gas results.

Consistent with USEPA policy, the Department recommends a VI investigation where structures are within 100 feet horizontally or vertically of shallow ground water contamination in excess of

the GWSL. Under a future use scenario, additional investigation may be necessary for undeveloped parcels using the same criterion. If the depth to the shallowest ground water exceeds 100 feet, a VI investigation is not required unless vertical preferential pathways exist and the CSM indicates there is a significant VI risk. Section 6.2.1 includes further guidance regarding this issue.

The 100-foot distance criterion for investigating the VI pathway does not consider the aerobic biodegradation of petroleum hydrocarbons, particularly the BTEX compounds. Depending on the site conditions, the criterion is likely to be too conservative for petroleum hydrocarbons. Therefore, the Department will utilize a 30-foot distance criterion (both horizontal and vertical) for petroleum related ground water contamination. (Refer to Chapter 9 for a clarification on petroleum hydrocarbons, or PHCs.) The 30-foot PHC distance criterion is based, in part, on the Pennsylvania VI guidance (2004).

If free product is present, the 100-foot distance criterion should be used, irrespective of the chemical composition of the free product.

3.2 Remedial Investigation

The Remedial Investigation (RI) Phase involves the evaluation of the VI pathway.

If the current results reveal exceedances of the generic screening levels (or insufficient data exists), a VI investigation workplan shall be prepared and implemented (Stage 4). Alternately, the option of implementing a remedial action as a proactive approach may be considered.

The Department recommends ground water (in most circumstances) as the first medium to be investigated for the VI pathway (Stage 4A). Unlike other states (e.g., California), the ground water table across most of New Jersey is relatively shallow and ground water data is readily available in the vicinity of the receptors. Thus, a ground water investigation is the appropriate first stage for most VI investigation workplans. Section 6.2, Ground Water Investigation and Sampling Procedures, should be consulted to ensure that the ground water data are both

representative and valid. In some instances, the Department may require sub-slab and indoor air sampling concurrent with ongoing ground water and exterior soil gas investigations. Depending on the site-specific CSM, the investigator may elect to conduct soil gas and/or indoor air sampling prior to initiating a ground water investigation.

In cases where soil contamination represents a potential source of VI, the use of ground water data and the GWSL alone are NOT appropriate. The investigator should employ soil gas and/or indoor air samples to assess whether soil contamination is a source of VI.

Assuming the potential vapor source is not in the unsaturated zone (soil), no further investigation of the VI pathway is required if appropriate ground water data are less than the NJDEP GWSL (and free or residual product is not present at the water table). However, if the ground water data exceed the screening levels, further investigation will be necessary.

The next stage of the VI investigation is the collection of soil gas samples (Stage 4B). Near slab (or sub-slab) soil gas sampling allows the investigator to quantify contaminant levels in soil gas immediately under or outside the foundation of the building. Section 6.3, Exterior or Near Slab Soil Gas Sampling Procedures, provides the particular requirements for collecting near slab soil gas samples. The procedures for collecting sub-slab soil gas samples are found in Section 6.4. For assessing undeveloped parcels, exterior soil gas sampling can be employed using a grid approach. The soil gas results from sub-slab, near slab, and exterior samples (where appropriate) can be compared to the NJDEP SGSL. Exceedances of the SGSL will require further evaluation of the VI pathway through the collection of indoor air data. Alternatively, the investigator may elect to implement a remedial action to address the VI pathway.

Recognizing the difficulties associated with background contamination (among several issues), indoor air sampling is typically the last step during a remedial investigation of the VI pathway (Stage 4C) that provides the most direct evidence regarding the air quality within a building. All other data (ground water, soil, sub-slab or near slab soil gas) simply reflect the potential for adverse impact on indoor air quality based on modeling or attenuation factors, and not the actual results. Thus, the Department recommends the collection of indoor air samples at this stage of

the investigation. Refer to Section 6.6 for more information on indoor air sampling procedures. All indoor air samples (including crawl space air samples) should be compared to NJDEP IASL. After consideration of background contamination and confirming the results, exceedances of the IASL may require remedial action to mitigate the vapor intrusion (Stage 8).

One of the decision points in the generic screening process is to determine whether the data are valid and representative. This is an all-inclusive phrase designed to address a variety of issues dealing with the usability of the data. The provisions of this step include:

- Was the sampling plan designed to investigate the VI pathway (including seasonal variability for indoor air samples), approved by NJDEP, and accurately followed by the investigator?
- Were the samples properly collected - consistent with the NJDEP Field Sampling Procedures Manual (2005) and this document?
- Is the investigator confident that the sampling equipment was not moved or otherwise tampered with (some sampling events are left in place for extended periods without supervision)?
- Were the samples validated (QA/QC) and determined to be acceptable?
- Was consideration given to potential background contamination?
- Were any other issues that might impact on the data's usability addressed appropriately?

Each of the above provisions should be answered affirmatively in order to proceed along the flow path. Any negative responses simply identify deficiencies in the data acquisition that require the collection of additional data. Unless the data are determined to be valid and representative (as discussed above), no conclusions can be made regarding the VI pathway.

3.3 Site-Specific Screening Options

At any point after Stage 3, the investigator can elect to utilize site-specific screening options as part of the VI investigation. While the generic GWSL are based on the presence of sandy soils, the Department has developed GWSL for Alternate Soil Textures (presented in Table 3 of the

document) based on loamy sand, sandy loam, and loam soil that result in less conservative screening levels. Laboratory soil grain size analysis, as described in Section 5.2, is required to justify the use of the GWSL for Alternate Soil Textures at a site.

Additional site-specific screening options that are available to the investigator (Stages 6 and 7) include (but are not limited to):

- a) Utilization of alternative soil gas sampling procedures (flux chambers, continuous monitoring, vertical depth profiling);
- b) Assessment of biodegradation for petroleum hydrocarbons (oxygen levels in subsurface soils, depth to ground water table);
- c) Development of alternate attenuation factors (with sub-slab or near slab soil gas);
- d) Modifications to the J&E Model (depth to vapor source and overlying unsaturated zone soil type);
- e) Use of recent chemical toxicity, risk assessment methodology or exposure parameter changes not yet reflected in the NJDEP guidance, in the generation of applicable IASL; and,
- f) Implementation of other appropriate site-specific screening options.

As discussed in Chapter 5 of the guidance, site-specific adjustments to the J&E model (including specific building parameters) may be submitted to the Department for review and approval. An institutional control on the property and regular monitoring (see Chapter 10) to protect against changes in future use/building construction may be required.

Approval of any site-specific screening option should be obtained from NJDEP in advance of its implementation as part of a VI investigative workplan. The workplan should incorporate provisions to verify the effectiveness of the site-specific screening option to adequately assess the VI pathway. In most cases this will involve the collection of additional field data. For example, the investigator may want to utilize site-specific depth to vapor source and/or overlying unsaturated zone soil type as part of the J&E modeling effort. The workplan should include a full

characterization of these parameters in the area of the inhabited building(s) being investigated (or undeveloped areas where future construction is possible).

In another case, multiple buildings may exist over a ground water plume. The investigator may propose to assess the VI risk using RI procedures for a representative number of "worst-case" buildings and apply the results to the entire site (or expand the investigation if necessary based on these results). The workplan should document the characteristic nature of the buildings selected based on ground water concentrations, locations on the site, soil type, building construction, and other factors NJDEP may deem appropriate. (Refer to Chapter 5 for further discussion on the Site-Specific Screening Procedures.)

3.4 Remediation and Monitoring

Once the VI investigation is complete, a selection of the appropriate remedial action shall be made. Consistent with N.J.A.C. 7:26E-5, a Remedial Action Selection Report (RASR) shall be prepared (Stage 8). Chapter 10, Remedial Actions, should be consulted for guidance on the applicable remedial alternatives.

An institutional control may be established within the limits of the ground water exceedance to address future use of the overlying land. Depending on the degree of exceedance and other site specific factors, current (and potentially future) inhabited buildings or environmental media may be monitored to assess any VI risk. Building construction can incorporate remedial designs to eliminate address the VI pathway. Engineering controls may be appropriate based on the results of the remedial investigation, current/future land use and site conditions.

A Remedial Action Workplan (RAW) shall be prepared upon the Department's approval of the RASR (Stage 9). The RAW must include discussions on long term monitoring and maintenance of the proposed remedial action (Stage 10).

Finally, the decision to terminate the proposed remediation upon remediation of the VI pathway (Stage 11) can be addressed in the RA Progress Report.

4.0 GENERIC VAPOR INTRUSION SCREENING LEVELS

4.1 Introduction

The Department has developed Ground Water Screening Levels (GWSL), Indoor Air Screening Levels (IASL) and Soil Gas Screening Levels (SGSL) to assist in the evaluation of potential VI impacts at sites under review. The applicable screening levels are listed in Table 1. The development of the screening levels is described in detail in Appendix G. As discussed in Chapter 3, exceedances of the screening levels indicate that VI is of potential concern and that further evaluation and/or potential remediation of the pathway is necessary.

The toxicity factors used in the development of the Department's screening levels are based on the USEPA *Region III Risk Based Concentration (RBC)* Table. USEPA Region III revises the RBC table twice a year (April and October) based on new toxicity factor information and any changes in the exposure parameters or calculation procedures. The Department will modify the affected screening level values and associated tables based on updates to the RBC table shortly after the information becomes available. The Department will also update the methodology used to develop the screening levels and the analytical reporting limits values as the state of the science advances.

Updates to the screening levels will be presented on the Department's web site at <http://www.state.nj.us/dep/srp/guidance/vaporintrusion/>. Modifications to the tables, since the last version, will be marked with a double asterisk (**) adjacent to the name of the affected chemical. It is recommended that users refer to the Department web site directly rather than rely on printed versions of the tables to ensure that the most current information is used.

4.2 Ground Water Screening Levels

The Department has developed screening levels for ground water in order to protect against unacceptable inhalation exposures to volatiles due to the migration of chemicals from contaminated ground water to indoor air. The GWSL are shown in Table 1. The Department

used the Johnson and Ettinger (J&E) Model with New Jersey specific parameters, when appropriate, in the development of the screening levels.

4.2.1 Application of the Ground Water Screening Levels

The USEPA states in its Draft Vapor Intrusion Guidance that the J&E model should not be used when the distance between the water table and the building foundation is less than five feet (USEPA, 2002b). Reasons for this include 1) the potential for seasonal fluctuations in the water table to bring ground water in direct contact with the building foundation, and 2) the potential for fill material, rather than native soil, to be present immediately under building foundations, and 3) the potential for the soil capillary zone to extend up the building foundation. The difficulty with the five-foot requirement is that New Jersey has many areas in the state with shallow ground water and the five-foot requirement would result in many locations being eliminated from consideration when using the ground water screening criteria. Since the screening level is relatively insensitive to the groundwater depth (see Appendix G), the Department has adopted slightly more liberal criteria for use of screening numbers calculated using the J&E model.

The Department's ground water screening criteria may be used where the ground water is as close as two feet below the building foundation when 1) the seasonal high water table does not reach the building foundation, 2) the water table does not extend into fill material directly under the building foundation, and 3) the top of the capillary zone does not reach the building foundation. Regarding Item 3, the capillary zone does not normally extend through fill material under buildings, which is typically coarse in nature. For situations where no fill material is present under a building's foundation, the top of the capillary zone may be estimated using Table 4-1. The capillary zone heights were calculated with the J&E model.

Table 4-1
Capillary Zone Heights for Select Soil Textures

| <i>Soil Texture</i> | <i>Capillary Zone Height (cm)</i> | <i>Capillary Zone Height (feet)</i> |
|---------------------|-----------------------------------|-------------------------------------|
| Sand | 17 | 0.6 |
| Loamy Sand | 19 | 0.6 |
| Sandy Loam | 25 | 0.8 |
| Sandy Clay Loam | 26 | 0.9 |
| Sandy clay | 30 | 1.0 |
| Loam | 38 | 1.2 |
| Clay Loam | 47 | 1.5 |
| Silty Loam | 68 | 2.2 |
| Clay | 82 | 2.7 |
| Silty Clay Loam | 134 | 4.4 |
| Silt | 163 | 5.3 |
| Silty clay | 192 | 6.3 |

As indicated in Table 4-1, the capillary zone is greater than two feet in height for some soils with silt and clay content. Therefore, the water table must be greater than two feet below the building foundation in those situations. Site specific field determinations may be made in these circumstances for soil texture.

Provided the above conditions are met, the Department's GWSL are judged to be adequately conservative for use at sites where unsaturated soil is present below the building foundation.

GWSL should not be applied where a building foundation is in direct contact with competent, massive bedrock containing discrete fractured zones if vertical fractures are very likely to act as preferential pathways for vapors (i.e., directly connecting contaminated ground water with building foundations). The GWSL may be used for soils that contain gravel, assuming they exhibit relatively homogeneous, isotropic conditions. The GWSL can also be applied (with Department approval) where the water table is in bedrock and nearby site specific data indicate there is unsaturated soil, fill, or geologic material below a building foundation through which subsurface air flow would approximate, or approach, porous media conditions. In many areas bedrock in the vadose zone and at the water table is so highly weathered and/or densely fractured that these conditions will be met even if deeper, more competent bedrock creates very heterogeneous flow conditions.

4.2.2 Degradation of BTEX Chemicals

It has been reported that oxygen levels above 4% are adequate for substantial degradation of BTEX chemicals to occur within a short distance in the vadose zone (DeVaul et al. 1997). For this reason, it has been suggested that an additional attenuation factor should be applied to the screening values in order to account for degradation of these chemicals. Suggested values for this degradation dilution factor are 3-10 (USEPA 2002b), 1-100 (Hers et al. 2004), 100-1000 (Fitzpatrick and Fitzgerald 2002) and 500-35,000 (Ririe et al. 2002). Thus far, the database is small regarding hydrocarbon attenuation factors. However, it appears that the additional attenuation factor is at least 10^{-1} (Hers 2004). For this reason, the GWSL listed in Table 1 for benzene, toluene, ethylbenzene and xylene are set at ten times the value calculated using the J&E model.

4.3 Indoor Air Screening Levels

Residential and nonresidential IASL to be used in the evaluation of indoor air analytical results are presented in Table 1 and are discussed below. The IASL are based on the *USEPA Region III Ambient Air Risk Based Concentrations (RBC)* Table. The NJDEP screening levels represent the higher of the health-based (RBC) indoor air values and the USEPA Method TO-15 analytical reporting limits (as defined in Appendix G). Screening levels indicating the need for more prompt action at a site are presented in Table 2. The basis of the screening levels is discussed in Appendix G.

4.3.1 Application of the Indoor Air Screening Levels

The applicable IASL, after consideration of the analytical reporting limits, are presented in Table 1. The values are presented in both ug/m^3 and ppbv units. When site data are compared with the screening levels, the user should ensure that the concentrations and the screening levels are both in the same units (ppbv or ug/m^3).

Consistent with the proposed Soil Standards regulations, the Department requires the use of the residential IASL in the evaluation of residential properties, schools and day care centers. There

may also be situations where other site-specific exposures occur that will be evaluated on a case specific basis.

The nonresidential IASL are applicable to industrial/commercial facilities where the adult is the receptor of concern. The Department's current policy requires that the nonresidential IASL are applicable to commercial/industrial sites when a discharge to the environment has occurred and the facility is not currently handling or using the subsurface contaminants of concern associated with the discharge. The evaluation of VI at facilities currently using the same chemicals present in the discharge impacted media (e.g., ground water) should include consideration of both the nonresidential screening levels and the applicability of the OSHA PEL to the subject building. As discussed in Chapter 10, the option to use the nonresidential IASL and/or the OSHA PEL is contingent upon obtaining an institutional control at the affected structure(s) to address potential future changes in site use. Nonresidential settings with sensitive populations (such as pregnant workers) will be handled on a site-specific basis.

While the Department does not subtract background air concentrations from the analytical results, site-specific background sources may be considered when interpreting indoor air data. Background contaminant levels, particularly ambient air results, may supercede the Table 1 values when higher since the Department does not require remediation to levels below background concentrations. Background determinations are made on a site-specific basis in consultation with the Department and as part of the overall multiple lines of evidence approach (see Chapter 8).

4.3.2 Alternate Indoor Air Screening Levels

As discussed in Chapter 5, Alternate IASL may be developed for a site as a site-specific evaluation based on chemical toxicity factor changes on IRIS or the USEPA Region III RBC Table that have not yet been reflected in the most recent NJDEP Vapor Intrusion Guidance document. Alternate IASL may also be developed based on recent changes in the risk assessment methodologies or exposure parameters that have not yet been included in the Department's Vapor Intrusion Guidance. As noted in Section 4.1, the Department will incorporate toxicity

changes from the USEPA Region III RBC Table used to develop the screening levels shortly after the updated information becomes available.

4.3.3 Rapid Action and Health Department Notification Levels

The Department has developed indoor air concentrations to determine when prompt actions are indicated to address the potential for adverse VI related impacts. Table 2 presents Rapid Action Levels (RAL) to be used when evaluating site related indoor air analytical data. The table includes RAL values for thirteen chemicals that the Department has found to be the primary contaminants that drive remedial actions at VI impacted sites.

The RAL values represent trigger levels for the initiation of a rapid action at occupied buildings to further investigate the VI pathway and/or minimize impacts to building occupants through an interim remedial measure. Since, as described below, the RAL values are based on a residential exposure scenario, nonresidential facilities that do not include residential uses (e.g., apartments), schools and/or day care centers, may be evaluated on a site-specific basis. The RAL values are not applicable to nonresidential facilities currently handling the VI contaminant(s) of concern that are subject to OSHA requirements for that chemical. Potential change in future use, however, must be considered in the evaluation of these sites.

By policy, the Department has based the RAL values on a factor of 100 times the cancer health-based residential IASL or a factor of 2 times the noncancer health-based residential IASL (presented in Table G-4). The Department has based the RAL value for trichloroethene (TCE) on the Health Department Notification Level (discussed below) for TCE due to the current controversy concerning the appropriate toxicity factor for the chemical.

Health Department Notification Levels (HDNL), developed in consultation with the New Jersey Department of Health and Senior Services (NJDHSS), are also listed in Table 2. These values, when exceeded in occupied buildings, represent levels that trigger the Department's referral of a site to the local health department and/or NJDHSS. The local health department and/or NJDHSS would use this information to make a decision in consultation with the NJDEP regarding the need for any emergency actions, such as the evacuation of an occupied building. On a case by

case basis, the health departments may also be notified when elevated indoor air levels below the HDNL are present in an occupied school, day care center, health care facility, or other structure with sensitive receptors.

The HDNL are based on one-half of the Agency for Toxic Substances Disease Registry (ATSDR) acute duration Minimum Risk Level (MRL) or 1,000 times the cancer health based residential indoor air value in Table G-4, whichever is lower. The intermediate duration MRL is used in the absence of an acute MRL.

Should the driver chemical at a site be a volatile contaminant that does not currently have a RAL or HDNL value, the Department's Environmental Toxicology and Risk Assessment (ETRA) unit may be contacted at 609-633-1348 to identify an applicable action level.

4.4 Soil Gas Screening Levels

SGSL developed by the Department for the evaluation of the VI pathway are presented in Table 1. The SGSL are used in the evaluation of representative and appropriate (see Chapter 6) sub-slab soil gas and/or near slab soil gas analytical results. Exceedence of the SGSL indicates the potential for VI that necessitates further evaluation of the pathway as outlined in Chapters 3 and 7.

As discussed in Appendix G, the SGSL are based on the higher of the health-based soil gas screening values and the soil gas analytical reporting limits presented in Table G-6. The health-based soil gas screening values were calculated by dividing the unrounded health-based indoor air values by an attenuation factor (α) of 0.02.

The attenuation factor and health-based soil gas screening values will be updated as the state of the science advances and as new information becomes available from USEPA. Site-specific attenuation factors and SGSL may be developed as a part of the remedial investigation (see Chapter 5).

5.0 SITE-SPECIFIC SCREENING PROCEDURES

This chapter discusses site-specific screening options available for the evaluation of the VI pathway. The use of a site-specific option to address the pathway will, in general, require the collection of more detailed site information. Departmental approval of the alternative approach should be obtained by the investigator prior to its implementation in the evaluation of a site. As discussed in Chapter 3, use of an alternative methodology must also include provisions in the associated VI investigative workplan to verify the effectiveness of the site-specific screening approach with actual field data. It should be noted that use of the options described below in Sections 5.1 and 5.2 is subject to the same limitations applied to the generic screening criteria (see Section 4.2.1).

5.1 Default Screening Numbers for Alternate Soil Textures

Using the J&E model, the Department has developed GWSL for Alternate Soil Textures, which are shown in Table 3. The levels were developed using the same “default” values and assumptions used in the generic GWSL except for those based on soil texture. Table 3 includes screening levels for loamy sand, sandy loam and loam soil textures. Values for vadose zone soil bulk density, total porosity, and water filled porosity are built into the J&E spreadsheet and set according to the selected soil texture. Laboratory soil grain size analysis of soil samples (Section 5.2.3) is required for acceptable use of the Table 3 screening levels as well as for other site-specific screening options discussed below. Acceptable use of the Table 3 screening levels requires that at least 75% of the soil vertical profile be as fine as the selected soil texture. If this criterion is not met, the coarsest soil texture must be used.

5.2 Site-Specific Use of the J&E Model for Calculation of VI GWSL

Site-specific modeling of VI may be accomplished using the J&E model. However, the allowed uses of the model for site-specific analysis are limited. While the input parameters of the J&E model are adjustable for site-specific conditions, some of them have no effect on the calculated screening level, many of them have only a moderate effect, and many parameters are not

amenable to site-specific measurement. Therefore, only a few parameters are practical for site-specific adjustment as summarized in Section 5.2.7. The potential for each class of input parameters to be adjusted is discussed in detail in Sections 5.2.1 through 5.2.6. Instructions for using the J&E spreadsheets have been published (USEPA 2004d). Only Version 3.1 (or later versions), available from the USEPA Office of Solid Waste and Emergency Response, may be utilized (www.epa.gov/oswer/riskassessment/airmodel/johnson_ettinger.html).

5.2.1 Chemical Properties

The chemical properties (organic carbon partition coefficient, Henry's law constant, diffusivity in air, diffusivity in water, water solubility, boiling point, critical temperature and enthalpy of vaporization) are fixed constants and not subject to change. While variable numerical values for these constants have been reported in the literature, the Department has decided to rely on the same data sources used in the USEPA Draft Vapor Intrusion Guidance (USEPA 2002b) and in the USEPA Soil Screening Guidance document (USEPA 1996a). See Appendix G for more information. Chemical properties will be updated as needed in future revisions of this document.

5.2.2 Toxicological and Exposure Parameters

USEPA Region III based unit risk factors (URF) and reference concentrations (RfC) have been used in the development of the screening levels presented in this document. While the Department will update the screening levels based on toxicity factor changes in the latest USEPA Region III Risk Based Concentration (RBC) Table, site-specific evaluations may be submitted that incorporate new IRIS or Region III based toxicity factors that have not yet been incorporated into the screening levels. The target risk level of 10^{-6} and the target hazard quotient of 1 may not be adjusted.

While the generic GWSL are based on a residential exposure scenario (as discussed in Appendix G), site-specific GWSL under a nonresidential (worker) exposure scenario may be developed for a site. The following USEPA exposure assumptions may be used for a nonresidential (worker) scenario:

- Exposure duration - 25 years. (Averaging time for noncarcinogens must be changed to 365 days x 25 years)
- Exposure frequency - 250 days/year
- Child adjustment factor (discussed in Appendix G) - may be eliminated under the worker scenario. This adjustment allows use of the J&E model output without multiplying the screening level by a factor of 0.74 (or 0.26 for vinyl chloride) that accounts for childhood exposure.
- The USEPA recommended averaging time for carcinogens may not be changed and is fixed at 70 years.

The exposure parameters used in the J&E model may be modified as a site-specific option based on recent changes in the risk assessment methodologies or exposure parameters that have not yet been included in this document.

Note that the option of using the above nonresidential exposure parameter values, or any other values other than the generic residential screening values (excluding toxicity factor and risk assessment methodology updates), will require an institutional control necessary to protect for future change in the use of the property.

5.2.3 Soil Texture

This parameter has a large effect on the calculated screening level and may be changed from the most conservative texture, sand, if adequate site-specific information is obtained. The use of soil textures finer than loam is allowed only if it can be demonstrated that these soils are not fractured. Alternately, a sand soil texture may be used when modeling these fine soil textures. Sand may also be used for soils that contain gravel, assuming they exhibit porous media conditions.

The Department's acceptance of an alternate soil texture shall be based on soil texture analysis. To establish soil texture, collect soil cores using a Shelby Tube, direct push sampler, or split

spoon. One representative boring within 10 feet of the structure will be sufficient for most single family homes with additional borings necessary for larger structures. The soil cores/samples should be collected continuously (every two or four feet depending on the length of the sampling device) from the base of the foundation depth to the surface of the static water level. A grain size analysis is then completed on the cores/samples. A variety of methods exist to determine grain size of a given soil sample. The Department will consider any of the following techniques acceptable: sieve analysis for the sand and gravel portions of a given sample with pipette or hydrometer measurements of the silt and clay fractions, rapid sediment analyzers, or electro-resistance multichannel particle size analyzers.

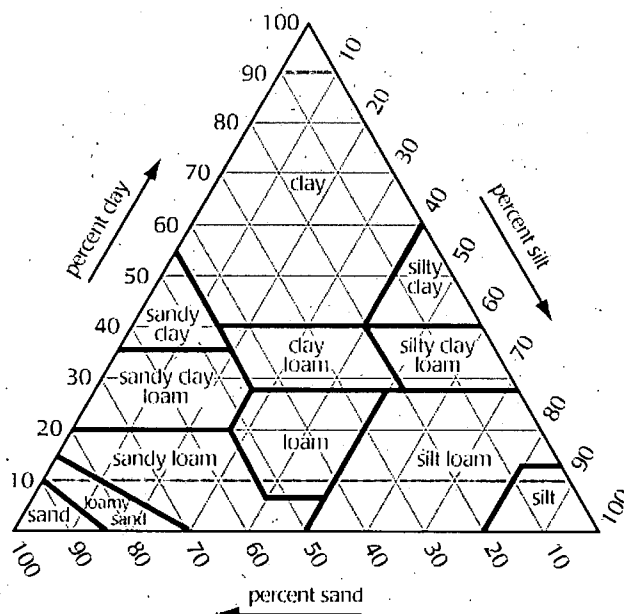


Figure 5-1

The percentages of sand, silt and clay determined by the chosen analysis techniques are then compared to the USDA Soil Texture Triangle to determine the soil texture classification (Figure 5-1 above). Under the USDA Soil Texture Triangle below, sands are considered particles between 0.05 mm and 2 mm in size, silts are between 0.05 mm and 0.002 mm and clays are less than 0.002 mm in size.

Site-specific J&E modeling using a single soil texture for the entire vadose zone requires that at least 75% of the soil vertical profile be as fine as the selected soil texture. If this criterion is not met, the coarsest soil texture must be used.

The Department's GIS has a Soil Survey Geographic Database (SSURGO) available which indicates the surface soil texture for most of New Jersey, with the exception of older urban areas (United States Department of Agriculture 1999). The SSURGO data layer should be examined in conjunction with the soil boring logs for a particular site of interest as a cross check to confirm that the correct soil texture is being used. This data may also provide a basis for requiring multiple soil boring locations per single family residence if it indicates horizontal changes in soil texture are likely across the building footprint.

When entering soil texture in the J&E spreadsheet, it must be entered in each cell where soil texture input is possible. The advanced spreadsheet (GW-ADV) has the capability of entering different textures for different soil strata. This should be allowed only when adequate soil boring data is available to indicate that these layers are continuous across the site under investigation.

5.2.4 Soil Physical and Chemical Properties

Practical, routine field methods are not available for determination of vadose zone bulk density, porosity and soil water-filled porosity. Thus, site-specific values for these parameters may not be substituted for the default values set according to soil texture. When soil texture is entered, the soil properties should be altered by clicking on the "Lookup soil parameters" in the J&E spreadsheet.

Soil vapor permeability is not used in the calculations for the Department screening levels. This parameter would be used to calculate the soil gas entry rate, Q_{soil} , but this latter parameter is instead fixed at the USEPA recommended value of 5 L/min when using the J&E spreadsheet. The Department does not allow the use of soil vapor permeability measurements for determining

Q_{soil} or screening level values because of the high level of variability of this measurement. It is only in soils immediately surrounding the foundation (i.e. the "zone of influence") where Q_{soil} is operative. Often, coarse grained fill material is placed below a building foundation, which is typically more porous than soils near the building foundation. Therefore, soil vapor permeability measurements of the soil surrounding the building are likely to be unrepresentative of the permeability conditions immediately below the foundation.

Soil organic carbon is fixed in the J&E spreadsheet at a fractional value of 0.002 and may not be changed. However, this value does not affect the screening level when the source of the contamination is the ground water (see Appendix G).

5.2.5 Building Parameters

Some building parameters may be adjusted site-specifically to calculate a site-specific ground water screening level. Note that adjustment of building parameters is an option that will result in an institutional control on the property and regular monitoring of the parameter by the responsible party to protect against future use modifications. The following parameters are allowed to be entered in the advanced version of the spreadsheet (Q_{soil} may also be entered in the screening version of spreadsheet).

Air exchange rate - The default air exchange rate is 0.25 exchanges/hour. This parameter may be adjusted site-specifically. The air exchange rate of the lowest floor of the building should be used. The ground water screening level is inversely proportional to the air exchange rate.

Soil gas entry rate - This parameter is dependant on many variables, including soil permeability, the building depressurization, the building perimeter, various crack parameters, and the soil vapor permeability. As discussed previously, calculation of the soil gas entry rate is subject to considerable uncertainty, particularly with regard to soil vapor permeability. Therefore, the use of the advanced J&E spreadsheet for calculation of this parameter from the soil vapor permeability is not allowed. A base value of 5 L/min is recommended by USEPA and has been adopted by the Department for a residential building. However, this value is inappropriate for

larger buildings, such as industrial or commercial buildings, or for warehouses. Unfortunately, field measurements of soil gas entry rates into these types of buildings are not available. As a practical solution to the issue of building size, the base Qsoil value of 5 L/min may be scaled up to accommodate larger building sizes. The J&E model predicts that the soil gas entry rate is proportional to the perimeter of the building foundation. Therefore the building size (building perimeter) may be used to adjust the base Qsoil value as follows:

$$Q_{soil} = 5 \text{ L/min} \times \frac{\text{perimeter}}{4000}$$

where Qsoil is the site-specific soil gas entry rate, perimeter is the length of the building perimeter in cm, and 5 L/min is the base soil gas entry rate for a default building perimeter of 4000 cm. The adjusted Qsoil value must be entered directly into the J&E spreadsheet (advanced version), rather than allowing the spreadsheet to calculate it. The building perimeter and height of the lowest floor should also be entered in order to adjust for the larger volume of the building. (The screening version of the spreadsheet allows for entry of a modified Qsoil value, but does not allow adjustment of building size.) This scale-up for building size results in a decrease in the attenuation coefficient (and a modest increase in the ground water screening level).

Procedures have been described for determining building-specific soil gas entry rates and attenuation factors from volatile tracer measurements in the sub-slab and indoor air. While such techniques may be used during vapor intrusion investigations, they are generally employed for research studies and formal guidance for their routine use is not yet available. Therefore, these techniques may be utilized to obtain additional evidence pertaining to vapor intrusion impacts, but may not be used in lieu of normal volatile contaminant sampling.

Building perimeter - If a modified soil gas entry rate is being used in the spreadsheet (see above), the correct building perimeter should be entered. The building perimeter also has a small effect on the diffusive entry of contaminant into the building, but this contribution is generally low relative to convective entry. The building perimeter may not be adjusted without also adjusting the value for Qsoil. An increasing building perimeter increases the value of Qsoil, but

causes a greater increase in building volume, thus increasing the attenuation coefficient and decreasing the ground water screening level.

Building height - If a modified soil gas entry rate is being used in the spreadsheet (see above), the height of the lowest floor of the building should be entered. The building height may not be adjusted without also adjusting the values of Q_{soil} and the building perimeter. At a constant air exchange rate, increasing the building height increases the value of the ground water screening level.

Building depressurization - This parameter is used along with other parameters (e.g., soil vapor permeability) to calculate soil gas entry rates. Since this calculation is not allowed (see above), modification of this parameter is not allowed. **EXCEPTION:** HVAC systems on some commercial buildings are run under positive pressure conditions (i.e., pressure in the building interior is greater than that on the exterior). In cases such as these, soil gas entry would be eliminated, and diffusion of contaminant through the building foundation would also be inhibited. If these conditions can be demonstrated, the VI pathway in this instance may be deemed incomplete and site-specific modeling is unnecessary. This may result in no further action for the VI pathway. Note that this option will necessitate an institutional control requiring positive pressure conditions be maintained and periodic monitoring by the responsible party to protect against any changes in future use and elimination of the positive pressure control.

Floor-wall seam crack width - This parameter affects the soil gas entry rate and also affects diffusive contaminant entry. As discussed above, this parameter is not allowed to be used to calculate a modified soil gas entry rate. Furthermore, diffusive contaminant entry is generally small relative to soil gas convection. Therefore, the effect of this parameter on the attenuation coefficient is small. The Department does not allow modification of this parameter.

Enclosed floor thickness - This parameter effects diffusive transport only. Since this transport mechanism is generally insignificant relative to convective transport, modification of this parameter is unnecessary and not allowed by the Department.

Depth of the building foundation - The depth of the building foundation is only relevant in that it affects the depth interval between the building foundation and the water table. This parameter may be adjusted site-specifically in the advanced version of the J&E spreadsheet (GW-ADV), or changed to slab depth (15 cm) in the screening version of the spreadsheet. However, the appropriate depth to ground water must also be entered.

5.2.6 Depth to Ground Water

The depth to ground water has a relatively small effect on the calculated GWSL. Site-specific adjustment of this parameter, however, is allowed and does not require an institutional control on the property.

5.2.7 Summary of Site-Specific J&E Modeling for Calculation of GWSL for the VI Pathway

For the J&E spreadsheets, USEPA guidance should be consulted (USEPA 2004d). Using procedures discussed above, the parameters in Table 5-1 may be adjusted in the J&E model. Appendix G provides further discussion regarding these input parameters, including sensitivity analyses.

Unless multiple soil layers or altered building parameters are being used, the GW-SCREEN spreadsheet should be used instead of GW-ADV. If a standard building foundation depth is being used (200 cm for basement construction, 15 cm for slab on grade construction), the GW-SCREEN spreadsheet is adequate unless other building parameters are being adjusted.

When calculating site-specific VI ground water screening levels for carcinogenic compounds, the J&E model output must be multiplied by 0.74 (or 0.26 for vinyl chloride) to account for the child exposure factor unless a worker scenario is being modeled.

For possible site-specific adjustment of the GWSL beyond those discussed in this document, the Department's case team should be consulted.

Table 5-1
Site-Specific J&E Model Parameters

| Parameters | Comments |
|---|---|
| Soil texture | - When soil texture is modified, the corresponding soil properties should be selected by clicking on the "Lookup soil parameters" button in the spreadsheet. When a single soil texture is used, the GW-SCREEN J&E spreadsheet may be used. When multiple soil layers are being entered, use of the GW-ADV will be necessary. |
| Depth to ground water | - Adjustable in either GW-SCREEN or GW-ADV |
| Depth of building foundation below grade | |
| Building air exchange rate | - Requires use of the GW-ADV spreadsheet. - Requires institutional control on property and regular monitoring to protect against future use scenarios and change in building construction. |
| Qsoil | |
| Building perimeter | |
| Height of first floor | |
| Exposure duration and averaging time for noncarcinogens | - Adjustable in either GW-SCREEN or GW-ADV. - Requires institutional control on property and regular monitoring to protect against future use scenarios and change in building construction. - Worker scenario |
| Exposure frequency | |
| Toxicity factors | - Requires restructuring the GW-SCREEN or GW-ADV database. |

5.3 Additional Site-Specific Options

The following site-specific screening options are available to the investigator in the VI evaluation of a site. These include (but are not limited to):

- Utilization of alternative soil gas sampling procedures (e.g., flux chambers, continuous monitoring, vertical depth profiling, angled direct-push sampling).
- Establish biodegradation values for hydrocarbons beneath a structure (oxygen levels in soil beneath the structure should be a minimum of 4%).
- Development of alternate attenuation factors (with sub-slab, near slab soil gas and/or indoor air data), as discussed in Chapter 6.3.
- Development of Alternate IASL as a site-specific evaluation based on chemical toxicity factor changes on IRIS or the USEPA Region III RBC table that have not yet been

reflected in the most recent NJDEP Vapor Intrusion Guidance document. Alternate IASL may also be developed based on recent changes in the risk assessment methodologies or exposure parameters that have not yet been included in the NJDEP Vapor Intrusion Guidance document.

- Implementation of other appropriate site-specific screening options.

Approval of any site-specific option should be obtained from the Department in advance of its implementation as part of a VI investigative workplan. All site-specific options must be supported by site-specific data. The workplan shall incorporate provisions (field data) to verify the effectiveness of the site-specific screening option to adequately assess the VI pathway (i.e., demonstrate the calculated result is verifiable in the site-specific situation for which it is being applied).

6.0 SAMPLING PROCEDURES AND INVESTIGATION REQUIREMENTS

6.1 Preparation of a Vapor Intrusion Workplan

If the Department requires the submission of a VI investigation workplan, the workplan shall be prepared consistent with the Technical Requirements for Site Remediation (N.J.A.C. 7:26E-4.2).

In the event that an investigator is conducting a VI investigation without departmental oversight, submittal of a workplan is not required. However, it is **highly recommended** that the investigator seek approval for any deviations from this guidance prior to conducting the sampling event. If the investigator decides to conduct the investigation without submitting a workplan and receiving approval, it should be recognized that any deviations from this guidance may result in rejection of the data. In addition, when submitting the results of the sampling event, the investigator should provide adequate rationale justifying any deviations from this guidance whether or not they were previously approved by the Department.

6.1.1 Conceptual Site Model

The CSM is the starting point for the preparation of a VI investigation workplan. As previously stated, NJDEP strongly recommends early development of a written, illustrated CSM that can be used to plan, scope, and communicate the development of a VI investigation workplan and any needed remedial actions.

The CSM will allow the investigator to better understand the source of contaminants, the pathways traveled, the receptors or entities potentially or actually exposed to contaminants, and the location of each component in relation to the others. Buildings with known sensitive populations (e.g., schools, day cares) should be identified early in the process and prioritized for investigation.

Armed with this information, a VI investigation workplan can be prepared.

6.1.2 General Issues

The most basic question an investigator asks when evaluating VI is “When do I have to assess this pathway?”

Utilizing the Decision Flow Chart (Appendix A), the initial decision points for the VI pathway are to assess the potential for VI (Stage 1) and determine whether the site necessitates a rapid action or Stage 2. An affirmative Stage 2 determination for occupied buildings will require the prompt investigation of the VI pathway to assess the necessity for remedial action. Confirmation of the VI-related exceedance of the RAL will necessitate that an interim remedial measure be implemented **immediately**.

More than likely, though, the investigator will move to the next decision point - evaluating existing data against the screening levels (Stage 3).

The Department considers ground water in excess of the NJDEP GWSL to be a potential source of VI that can adversely impact indoor air quality of nearby structures. Consistent with USEPA, the VI pathway warrants investigation when a structure is “located within approximately 100 feet laterally or vertically of known or interpolated soil gas or ground water contaminants ... and the contamination occurs in the unsaturated zone and/or the uppermost saturated zone.” (USEPA 2002b) Further clarification on the distance criteria, including the adjustment for petroleum hydrocarbons, can be found in Chapter 3.

Existing soil gas (sub-slab or near slab only) or indoor air data should be compared to the NJDEP SGSL and IASL, respectively. Exceedances of these screening levels will necessitate further evaluation and possible remedial action of the VI pathway.

6.1.3 Investigative Tools

There are a number of investigative methods for assessing the VI pathway, involving ground water, soil gas and indoor air sample collection.

6.1.3.1 Ground Water Sampling

In most situations, ground water will be the first medium to be evaluated for the VI pathway (Stage 4A). A site-wide remedial investigation will require the characterization and delineation of ground water contamination. The extent of the ground water plume, as well as the concentrations of the contaminants, will allow for an initial assessment of the VI pathway. Any exceedance of the NJDEP GWSL will necessitate further evaluation and probably more field investigation.

Section 6.2 below and the Technical Requirements for Site Remediation (N.J.A.C. 7:26E) should be followed for all ground water investigations. Quality assurance issues (e.g., QA samples, analytical methods, deliverables) for ground water sampling should be consistent with the most recent version of the NJDEP Field Sampling Procedures Manual.

As a general rule, the collection of soil gas or indoor air samples is not recommended prior to a basic assessment of the site hydrogeology, including soil stratigraphy, ground water depth and flow direction, and contaminant concentrations. False assumptions may be reached on the VI pathway based on an incomplete picture of the site hydrogeology (as defined in the CSM). It should be understood, though, Stage 2 may necessitate the collection of sub-slab soil gas and/or indoor air samples prior to acquisition of sufficient ground water data due to the urgency of the potential human exposure. The presence, quantity, and location of NAPL in the vadose zone may also indicate that the collection of soil gas and/or indoor air samples should precede collection of ground water analytical data.

6.1.3.2 Soil Gas Sampling

An exceedance of the NJDEP GWSL will necessitate further investigation of the VI pathway. Soil gas sampling (Stage 4B) is the most logical next step in the VI investigative process.

In this guidance, NJDEP defines soil gas results based on the location of the sample - sub-slab (below the foundation slab), near slab (within 10 feet horizontally of the foundation), or exterior

(outside of the 10-foot perimeter). In addition, data can be obtained from passive soil gas sampling procedures.

Depending on the investigative scenario encountered, different applications of soil gas sampling may be appropriate.

When ground water contamination in excess of the GWSL extends near or under a building (using the appropriate distance criteria), the Department recommends the collection of sub-slab soil gas samples to verify the presence of elevated soil gas concentrations immediately below the building foundation/slab. The sub-slab soil gas results will provide empirical data essential in properly evaluating risk to human receptors within the structure.

When the collection of sub-slab soil gas samples is not feasible, the results of near slab soil gas sampling may be utilized (with the Department's approval) to determine whether the VI pathway is currently complete for a particular building. Refer to Sections 6.3 and 6.4 (Exterior or Near Slab Soil Gas Sampling Procedures and Sub-Slab Soil Gas Sampling Procedures, respectively) for additional requirements.

Undeveloped parcels without existing structures present a unique situation for the investigation of the VI pathway. The collection of sub-slab soil gas or indoor air samples is not possible without a structure on the parcel. In this case, the Department recommends as an option that exterior soil gas samples be utilized to assess the potential for VI under a future use scenario. A grid sampling approach (approximately 100 x 100 feet) should be employed across the site and biased towards the highest concentrations within the ground water plume. The suggested soil gas depth is 8-10 feet below ground surface (equivalent to the depth of a typical basement). Site-specific modifications to the sample depth may be appropriate based on current municipal zoning, projected construction activities, or hydrogeological parameters.

Only in situations where the exterior soil gas investigation is being conducted to assess a future use scenario at an undeveloped parcel should the results be compared to the NJDEP SGSL.

Exterior soil gas samples can also be employed to assist with the delineation of the ground water plume. However, final plume delineation should be supported by the collection of confirmatory ground water samples at strategic locations. In these cases, a mobile lab employing USEPA Method 8260B (or similar methods) may expedite the investigation and allow the flexibility to modify the sampling strategy in the field (Triad approach).

The results of the sub-slab and near slab soil gas samples are compared to the NJDEP SGSL.

The NJDEP SGSL are applied to samples collected at a minimum depth of 5 feet below the ground surface and in the vadose zone no closer than one foot above the capillary fringe. A shallow ground water table may prevent the collection of representative or valid soil gas samples due to high moisture content within the gas sampled and/or dilution due to atmospheric air being drawn down from the surface. The only exception to the 5-foot depth rule is for soil gas samples collected from a central location below a shallow or at grade impermeable slab, including driveways, parking lots, building slabs, and garage floors.

In situations where contaminated unsaturated soils are the primary potential source, sub-slab or near slab soil gas samples are the principal mechanism for investigating the VI pathway (other than indoor air samples).

Underground storage tank sites or sites where chlorinated solvents are used in buildings or facilities at the surface (e.g., dry cleaners, vapor degreasers) may have contamination in the vadose zone due solely to vapor leaks. In these cases, soil and/or ground water data may not identify the VI source. Soil gas data are the preferable investigative tools where vapor leaks (or vapor clouds) are suspected. The vapor cloud phenomenon is discussed in Chapter 2.

Sites that involve contaminated unsaturated soils or vapor leaks are two examples where a vertical profile of soil gas concentrations may assist in the investigation. Vertical profiling can better clarify the source(s) of VI by evaluating the distribution of chemical concentrations over a defined depth. If a ground water plume under a structure is the suspected source, soil gas concentrations should increase as the depth of the soil collection increases. Deviations from this

general assumption may suggest an alternative source, such as preferential pathways, vapor leaks or vadose zone soil contamination.

Sub-slab or near slab soil gas samples may also be more appropriate when obtaining truly representative ground water data is not possible or is impractical.

Lastly, passive soil gas sampling may be applicable to the preliminary delineation of the ground water plume. Final plume delineation should be supported by the collection of confirmatory ground water samples at strategic locations.

6.1.3.3 Indoor Air Sampling

Indoor air sampling is generally the last investigative step in the evaluation of the VI pathway (Stage 4C). Due to legitimate concerns over background sources, indoor air results provide a unique challenge to investigators (refer to Chapter 8, Background Indoor Air Contamination, for additional information). The Department recommends the collection of sub-slab and ambient air samples in conjunction with indoor air sampling events (Stage 4C) to assist in the evaluation of background contaminant sources.

Despite the problems, indoor air sampling is often necessary to properly assess whether the VI pathway is complete. These situations include:

- Exceedances of the SGSL;
- Shallow ground water table that prevents the collection of soil gas data;
- Site-specific approach is utilized which requires supplemental data in support of the conclusions;
- Preferential pathways exist that may negate or limit the usefulness of ground water or soil gas data;
- Stage 2 conditions that require a more immediate response;
- Volatiles in bedrock near or at the surface which eliminates the use of the J&E Model; and,
- Other site-specific factors.

Since indoor air sample locations are a critical issue in the ultimate assessment of the data, the VI investigation workplan should clearly identify the criteria that will be employed in this selection process. Refer to Conducting a Building Walkthrough and Survey (Section 6.5) for additional guidance on this phase of the investigation.

An ambient air sample provides background concentrations outside of the building being investigated at the time of the indoor air sampling event. When using USEPA Method TO-15, the canister used for the ambient air sample should be randomly selected from the canisters sent by the laboratory and placed outside of a building that is being sampled. The ambient air sample shall have the same sample collection time and be analyzed in the same manner as the interior sample. The investigator should clearly designate where the sample is collected and the site conditions at the time of sampling. The investigator also should be aware of the weather conditions during the sampling event. It is highly recommended that the canisters be placed in a secure outside location and not in front of a building. Ambient air samples should be taken at breathing zone height and as far from auto traffic or other potential sources as possible.

The number of ambient (outside) canisters recommended is a minimum of 1 per sampling event with the maximum of twenty (20) samples being associated with each ambient (outside) canister. However, if the sampling event occurs over multiple days, additional ambient (outside) canisters may be recommended at the discretion of NJDEP. Additionally, if the spatial arrangement of the sampling points is dispersed and background cannot be easily defined, additional ambient (outside) canisters may be recommended.

In situations where ambient levels for contaminants of concern are expected to be elevated based on the nature of the commercial/industrial/retail operation, the investigator should consider avoiding the collection of indoor air samples. For example, at active gasoline service stations, if ground water contaminant concentrations exceed the GWSL, the Department recommends the collection of sub-slab soil gas samples where possible in lieu of indoor air samples. If the sub-slab results are in excess of SGSL, an institutional control may be required at the site until it can be demonstrated the site contaminant concentrations do not represent a VI risk.

Depending on the site conditions, the volatile concentrations in ground water, and seasonal variability, one round of indoor air samples will likely not be sufficient to verify the presence/absence of the VI pathway. A second (or confirmation) round of indoor air samples may be appropriate. At a minimum, a confirmation sample is necessary to eliminate the VI pathway when the initial sample is collected outside the winter/early spring timeframe (November through March). Modifications to this provision may be appropriate based on site-specific information.

In the case of initial indoor air results that exceed RAL, confirmation samples should be collected **immediately** to verify these exceedances.

6.1.3.4 *Soil Sampling*

At this time, generic screening levels for soil results have not been developed. Soil gas and indoor air results can be evaluated to assess the vapor potential from contaminated soils. Otherwise, a site-specific determination will have to be made as to whether further investigation of the VI pathway is warranted for contaminated soils.

6.1.4 Preferential Pathways

Due to the nature of vapor migration, all VI investigation workplans must assess the presence of preferential pathways.

The Pennsylvania Department of Environmental Protection (2004) defines preferential pathways as:

“...a natural (e.g., shallow rock or vertically fractured soil) or manmade (e.g., buried utilities) feature that creates a sufficiently direct pathway from a source to a receptor to make the use of the default model for predicting indoor air concentrations unacceptable.”

The investigator should evaluate the possibility of interconnections between ground water and any subsurface utilities (e.g., storm sewers, sanitary sewers, water lines). In these cases, the depth of the invert, the diameter of the conduit, and the construction specifications of utility lines should be determined. The investigator should also determine whether any utilities may be acting as conduits for vapor migration, either along the utility's backfill or within the utility itself. This determination should include, but not be limited to, visual inspection and the use of field screening instruments (with appropriate detection limits based on the SGSL). Additional information on assessing utility corridors as part of a VI investigation can be found in the State of Wisconsin guidance document (2000).

Based upon the results of this evaluation, the investigator may be required to canvass the immediate area of concern, locate all subsurface utilities and basements, and determine the presence/absence of organic vapors in accordance with N.J.A.C. 7:26E-4.4(h)3.viii. The exact locations of all subsurface utilities and basements should be plotted on a scaled site map. Depending on the site conditions, periodic inspections of the subsurface utilities may be required with readings of oxygen levels, and lower explosive levels (LEL). In addition, the presence of organic vapors within the utility corridors should be documented by collecting passive or active soil gas samples.

6.1.5 VI Report Requirements

The VI Report should address a series of issues related to documenting the sampling event. In addition to the requirements in N.J.A.C. 7:26E-4.8, the following provisions should be included in the VI Report:

1. Copies of the Indoor Air Building Survey and Sampling form;
2. Scaled site maps identifying the site, adjacent streets, buildings sampled (soil gas/indoor air), ambient air sample locations;
3. Photographs of sample locations (as appropriate) or other pertinent site features;
4. Readings from field instrumentation;
5. Any documentation, including scaled maps, on the assessment of preferential pathways; and,

6. Scaled floor plans that note location of indoor air and sub-slab soil gas samples, observed stains and major cracks in slabs/foundations, sumps, French drains, existing radon systems, chemical storage areas (or other potential background sources), HVAC systems, utility entrances into buildings, etc.

6.2 Ground Water Investigation and Sampling Procedures

Section 6.2 discusses: 1) saturated zone features affecting VI; 2) use of pre-existing ground water data; and 3) obtaining new ground water data to evaluate this pathway.

6.2.1. Saturated Zone Features Affecting Vapor Intrusion

Many of the concepts and properties discussed below are more applicable to subsurface formations where the ground water flow regime is relatively homogeneous (e.g., unconsolidated or sedimentary formations), however, more heterogeneous flow regimes are also addressed in several discussions. Topics include:

- Clean Water Lens
- Depth to Saturated Zone and Stratigraphy
- Fluctuations in Depth to Saturated Zone
- Complex Hydrogeologic Settings
- Proximity to Preferential Pathways
- Potential for Contaminant Degradation.

6.2.1.1 *Clean Water Lens*

Published and non-published research and case data indicate that ground water concentrations of volatiles in a small depth interval close to the water table are a better predictor of the presence, and relative concentrations, of volatiles in soil gas or indoor air than are volatile levels in slightly deeper saturated intervals (Fitzpatrick and Fitzgerald 2002; Hers and Rees 2005; McAlary et al. 2004; Rivett 1995; Marrin and Thompson 1987). If a clean water lens exists above the volatile

contamination, it can act as a barrier to volatilization from deeper ground water (Rivett 1995). This could reduce or prevent VI into overlying buildings (see Figure 2-6).

As a ground water plume migrates downgradient from its source area it is subject to a number of processes. Some of the processes favor the formation of a clean water lens while others may prevent its formation or may eliminate such a lens soon after it forms. Where precipitation and other waters (lawn irrigation, septic systems, leaking sewer or water supply lines, etc.) can infiltrate and/or percolate to the water table through clean soil/sediments, a clean water lens is likely to form (Weaver and Wilson 2003; USEPA 2001e).

Other stratigraphic and/or hydrogeologic properties (e.g., layer with higher permeability, downward hydraulic gradient) could also cause a plume to dive in the downgradient direction (Weaver et al. 1999), possibly thickening the clean water lens as ground water migrates away from the source area. Upward hydraulic gradients and minimal infiltration of precipitation due to impermeable surface cover both discourage formation of a clean water lens. A clean water lens may form and disappear multiple times depending on factors discussed in Subsection 6.2.1.3.

Where a clean water lens is an important element of the CSM, multi-depth sampling (i.e., vertical profiling) within discrete intervals in a well or boring may be appropriate. An increase in ground water density due to contamination with DNAPL is generally not a cause for a diving plume (Schwille 1988).

A clean water lens that is thicker than the annual water table fluctuation range can be a significant barrier to off-gassing of volatiles from ground water to soil gas. If a clean water lens is thin, relative to short term, seasonal, and/or longer term drops in the water level (natural or manmade) it is likely that a falling water table will expose a plume to the vadose zone (see Figure 2-7).

6.2.1.2 *Depth to Saturated Zone and Stratigraphy*

The water table can be described as the shallowest depth at which ground water will freely flow into wells, or other ground water sampling devices. The depth to the regional water table and/or any perched saturated zone(s) needs to be determined in the vicinity of buildings at risk for VI. The vertical distance between the most shallow saturated zone and building foundations should also be determined. A “perched” water table is one with unsaturated materials beneath it, and usually occurs only where a low permeability layer is present in the unsaturated zone and recharge is sufficient to exceed the percolation rate through this layer.

As indicated in Section 4.2, where the top of the saturated zone is in very fine grained soil or sediments, the intergrain pores (i.e., original or primary pores) will be quite small, and as a result, the capillary fringe above the water table will be quite thick; it also can be fully saturated closer to the water table. The presence and concentration of volatiles in such a saturated interval just above the water table would greatly affect off-gassing into the vadose zone, however it may be impractical to obtain a ground water sample from that interval. In such soils, representative soil gas volatile data will likely be a much better indicator than ground water data of the VI risk. This is also likely where vadose zone soil borings indicate a thick, laterally extensive, organic rich layer (Hughes et al. 1996).

Boring or test pit logs in the area of a VI investigation should be used to:

- evaluate the soil profile, soil type and texture throughout the profile;
- look for stratigraphic changes or soil horizons indicative of high moisture content, a perched water table, or high organic carbon content; and,
- evaluate characteristics of the strata immediately below and above the water table.

The depth of the water table and/or first zone of saturation should be determined in order to:

- help determine ground water flow direction (with surveyed ground surface elevations);
- decide appropriate media for further investigation; and,
- determine the depth of ground water sampling.

6.2.1.3 Fluctuation in Depth to Saturated Zone

Changes in water table elevation may increase or decrease the risk of VI. The cause of the water level change and the proximity and nature of the source of the ground water contamination (e.g., age, size) affect the potential for VI. The water table elevation fluctuates and perched saturated zones may dry up seasonally or only exist periodically after precipitation events. If a perched saturated zone is present, extensive enough, and clean, it could prevent migration of vapors through it, or around it, from underlying contaminated ground water.

Where free product has migrated along the water table, a rising water level could increase the risk of VI to nearby structures, especially if the rise in water level was not caused by local ground water recharge (e.g., flooding near a river, swollen from rain or snow melt in locations far upstream). If the overlying soil/sediment is clean and only dissolved phase ground water contamination is present, a rise in water level due to local recharge may form a clean water lens and reduce the risk of VI.

Significant fluctuations in the water table elevation also affect the predictability of VI using analytical modeling approaches where ground water quality is the source input parameter. Proper ground water sampling design may overcome this potential limitation but use of ground water samples that represent worst case conditions and/or use of soil gas data is more acceptable to NJDEP for modeling in such situations.

6.2.1.4 Complex Hydrogeologic Settings

Heterogeneity in subsurface media could have a significant impact on whether volatiles in saturated zones become a source for VI. Information on the locations and depths of near surface features such as clay, till or gravel layers/lenses and depth to bedrock must be considered for an adequate evaluation. Such features should be taken into account when determining saturated zone sampling depth intervals and whether ground water data can be utilized to evaluate VI risk.

For example, sampling of potable wells drawing from a bedrock aquifer underlying indoor air receptors may show volatile contamination, but ground water in the overburden above the bedrock may be clean. If there is bedrock immediately beneath a building or bedrock outcrops nearby (such that it bisects the saturated zone in the overburden near the structure), vapors from the bedrock aquifer contamination may be able to migrate to the ground surface if unsaturated vertical fractures, faults, solution channels or other secondary pores/openings provide a migration conduit. In that situation, ground water quality in the bedrock near such features may be just as relevant as nearby shallow ground water quality in the overburden. However, given the difficulty and expense of bedrock investigations, subsurface gas sampling and/or indoor air sampling would be a more practical and, probably, a more accurate investigative approach where bedrock aquifer contamination is likely to cause VI.

6.2.1.5 Proximity to Preferential Pathways

Preferential pathways in the unsaturated zone (defined in Section 2.2.4) could allow rapid and/or laterally significant vapor transport. To the extent it is feasible and safe, VI investigations should consider the proximity of contaminated ground water to unsaturated preferential pathways. The 30- or 100-foot criteria (see Section 3.2) may not be adequately conservative where preferential pathways connect structures with areas of subsurface NAPL contamination or ground water/soil concentrations indicative of the presence of NAPL (e.g., plume source area with suspected residual DNAPL is more than 100 feet side gradient of structures but buried utility bedding connects it with structures). This is more likely a concern for contaminants that do not aerobically biodegrade readily.

6.2.1.6 Potential for Contaminant Degradation

Many contaminants associated with petroleum hydrocarbons, including benzene, toluene, ethylbenzene and xylene (BTEX) compounds are readily biodegraded in the vadose zone (Thompson and Marrin 1987). As such, they are less likely to complete the VI to indoor air pathway than most chlorinated VOC. Even where LNAPL occurs in close proximity to structures, rapid biodegradation in the vadose zone may preclude a complete pathway. Therefore,

soil gas sampling (e.g., vertical profiling of volatiles, O₂ and CO₂) will usually be more relevant than ground water sampling for evaluating the risk of VI when GWSL are exceeded. Biodegradation of petroleum hydrocarbon contaminants is discussed in Chapter 9.

6.2.2 Use of Pre-Existing Ground Water Data

In many situations shallow ground water data that are already available prior to initiation of a VI investigation are sufficient to use as part of a VI investigation, especially if ground water contamination has been delineated and the plume has reached steady state conditions (i.e., no longer expanding). In deciding whether existing data are sufficient, consideration should be given to the site-specific CSM and the data should be from wells screened across the water table at the time of sampling. If the vertical thickness of the water column in a well is greater than 10 feet, supplemental data may be recommended on a case by case basis.

In addition, the likelihood of significant vertical changes in ground water quality near the water table, the sampling method used, the construction of existing wells sampled (e.g., screen length and placement across water table), the type of contaminants present, and heterogeneity of the vadose zone and shallow saturated zone media will likely be the most important factors in determining whether existing data are sufficient. Proposals to supplement existing ground water data with some type of soil gas data, instead of new ground water data, may also be considered.

6.2.2.1 *Interpolation of Nearby Data*

If ground water data immediately upgradient from the structure are not available, surrounding data points can be used to construct contaminant iso-concentration maps. However, this should only be done if data points are available on at least two sides of a structure. Complex geologic settings or the anticipated presence of steep concentration gradients warrant a denser sampling grid.

6.2.2.2 *Use of Drinking Water Well Data*

Since 1985, New Jersey statutes and/or regulations have required that private or public drinking water supply wells be constructed with at least 50 feet of casing. For this and other reasons it is likely that few drinking water wells in New Jersey are screened/open across the water table. It is much more likely that they draw ground water from depths at least 10 feet or more below the local water table. It is also likely that drinking water supply wells in consolidated bedrock formations are not often drawing water from water bearing zones that are in widespread, direct contact with the vadose zone immediately above the well. Therefore, the presence of volatiles in private or public drinking water wells should be considered a possible basis for further investigation, but in most situations the data should not be compared to GWSL.

6.2.3 Obtaining New Ground Water Data to Evaluate the VI Pathway

If the evaluations discussed above indicate that new or additional ground water data are needed to complete the VI investigation, the goal of the sampling effort should be to determine volatile concentrations in shallow ground water beneath or near potential structures.

Direct push sampling methods and **passive diffusion bag samplers** are two ground water sampling methods NJDEP recommends for obtaining discrete interval samples (i.e., from a distinct, defined interval) in the uppermost intervals of shallow ground water. Vertical profiling in discrete intervals within the top 10 feet (or less) of the saturated zone may be recommended (see subsection 6.2.3.2 below). **Low flow purging and sampling** may provide adequate data to evaluate this pathway in many situations. Volume-averaged purging and sample collection (i.e., conventional method) is not well suited to generate new ground water data specifically for VI evaluations.

Table 6-1

Ground Water Sampling Methods for Vapor Intrusion Investigations

| Methods | Sampling Procedure Guidance documents | Advantages or Disadvantages |
|---|--|---|
| Direct Push and Alternate Ground Water Sampling Methods (alternate to permanent monitoring well installation) | NJDEP <u>Field Sampling Procedures Manual</u> (2005) Section 6.9.2.1 found at www.nj.gov/dep/srp/guidance/fspm . | <ul style="list-style-type: none"> • Can do vertical profiling • Can do discrete interval sampling at defined depth intervals • Rapid sampling at multiple locations • More difficult to repeat sampling in same locations • Some methods limited to unconsolidated formations |
| Passive Diffusion Bag Samplers (PDBS) | NJDEP <u>Field Sampling Procedures Manual</u> (2005) found at www.nj.gov/dep/srp/guidance/fspm .; USGS <u>User's Guide for Polyethylene-Based PDBS to Obtain VOC Concentrations in Wells, Part 1</u> available at: http://www.itrcweb.org/gd_DS.asp ; ITRC <u>Technical and Regulatory Guidance for Using PDBS to Monitor VOC in Groundwater</u> available at http://www.itrcweb.org/gd_DS.asp . | Can use existing wells for: <ul style="list-style-type: none"> • Vertical profiling in discrete intervals • on going monitoring May not be adequate where/for: <ul style="list-style-type: none"> • VOC highly soluble in water (such as MTBE) • in-well vertical flow occurs • permeability is very low |
| Low Flow Purging and Sampling (LFPS) | NJDEP <u>Field Sampling Procedures Manual</u> (2005), Section 6.9.2.2 and 6.9.2.3 found at www.nj.gov/dep/srp/guidance/fspm . | <ul style="list-style-type: none"> • May generally target interval closer to the water table in some settings • Discrete interval sample not obtained |
| Volume-Averaged Purge and Sample Collection | NJDEP <u>Field Sampling Procedures Manual</u> (2005), Section 6.9.2.4 found at www.nj.gov/dep/srp/guidance/fspm . | Not recommended to generate new ground water data specifically for VI investigations |

Sampling guidance for VI investigations may differ from other NJDEP guidance in the documents listed in Table 6-1 because of the objective to determine very shallow ground water quality.

6.2.3.1 Ground Water Sampling Location

Ground water samples should be collected as close, horizontally and vertically, to the structures as possible because concentrations are not always relatively uniform within a plume due to heterogeneities in source areas and in the subsurface media. In choosing locations horizontally, bear in mind that ground water plumes are usually elongated in the direction of ground water

flow with little lateral mixing; therefore, ground water concentrations can change dramatically over short horizontal distances, especially near the lateral edges of a plume. Given the 100 and 30 foot distance criteria between vapor source and potentially affected structures, a more detailed delineation of the extent of ground water contamination may be appropriate in some situations.

Changes in surface cover that significantly affect the amount of infiltration upgradient from structures should be considered in choosing sampling locations. For example, if there is a stormwater retention pond or a transition from a mostly paved surface to a vegetated park/open field located between the upgradient edge of a plume and a structure, a sampling location downgradient of the pond or vegetated land should be selected.

6.2.3.2 Sampling Depth Intervals

An existing monitoring well should be considered adequate for evaluating the appropriate depth interval(s) if the screen/open borehole intersects the water table throughout the year (i.e., a water table well), and the thickness of the water column in the well is approximately 10 feet or less. For new water table wells installed as part of a VI investigation, a 5 to 10 foot screen is generally recommended unless this conflicts with other site investigation objectives. Additional construction recommendations are discussed below under "Installation of New Monitor Wells."

If a perched water table exists above the regional water table, NJDEP may require that samples be collected from both the perched zone and regional shallow aquifer. Perched saturated zones that are laterally contiguous under/near structures, exist year round, and are below nearby building foundations should be sampled if they are of sufficient thickness that a sample can be obtained. Professional judgment must be used in more complex situations but, in the above scenario, sampling of the regional water table may not be vital to investigating the VI pathway.

In some situations, NJDEP will consider use of vertical profiling of volatile concentrations in ground water (within the top 6, or the top 10 feet, of the saturated zone) to determine whether or not additional investigation of the VI pathway is needed.

Vertical profiling is recommended or may be warranted where:

- A clean water lens is likely to be present;
- Certain site-specific screening options will be used; and,
- Direct push or any discrete-interval ground water sampling method is used to obtain new data to evaluate this pathway.

Sections 6.2.1.1, 2.4.3 and 2.4.4 cover the processes and site characteristics that favor the formation of a **clean water lens**. Development of the CSM should include evaluation of whether a clean water lens is likely to be present and/or if volatile levels below the GWSL are likely to be at or near the water table.

If a **site-specific** GWSL has been approved by the Department (excluding Table 3) or if ground water data will be used to develop a site-specific ground water to indoor air attenuation factor, vertical profiling may be warranted. Large vertical changes in ground water volatile concentrations often occur within a 5 to 10 foot vertical interval (Vroblecky 2001; Reilly and Gibbs 1993; and Puls and Paul 1998). If a clean water lens is not present these changes are usually not relevant to whether the GWSL are exceeded because the GWSL are very conservative. These changes may be relevant if the above options are utilized. Flexibility regarding this recommendation is reasonable based on site-specific characteristics or data (e.g., existing site data may indicate that vertical changes in volatile concentrations are likely to be negligible).

Vertical profiling is recommended however if a site-specific GWSL has been approved by the Department (not including the levels in Table 3) and if ground water data will be used to develop a site-specific ground water to indoor air attenuation factor.

If **discrete-interval ground water sampling methods** are used, vertical profiling may often be appropriate. However, site-specific data may suggest that significant vertical changes are unlikely or could not be detected by some methodologies due to site conditions (e.g., vertical flow within a well screen/open hole saturated interval).

Where vertical contaminant profiling is done, NJDEP generally recommends sampling within, at least, the top 6 feet of the saturated zone, and possibly the top 10 feet. Site-specific considerations may warrant altering the total depth interval for profiling.

Changes in regional water-table elevation (~1 to 3 feet) are relatively common. Profiling should extend to 10 feet below the water table (bwt) in situations where/when significant drops in the water table elevation (more than about 4 feet) are likely. Significant decline in the water level elevation may be caused by shallow or deeper zone ground water withdrawals, changes in surface cover or management of stormwater runoff, and prolonged drought.

The exact depth intervals below the water table that should be targeted as part of vertical profiling depend on sampling methodology and site-specific information. Generally, at least two different depth intervals within the top 6 feet of the saturated zone should be targeted for sampling. Method specific guidance is given below. If profiling extends to 10 feet bwt, one sample from the 6 to 10 foot interval is generally recommended for any method utilized.

Profiling should be done in at least one boring or well. Multiple borings/well locations may be recommended where a large number of structures overlie a large plume.

Vertical profiles of shallow ground water contamination may enable a more precise evaluation of the current and potential future risk of VI in some situations.

6.2.3.3 Direct Push and Alternative Ground Water Sampling Methods

Where the geologic formation allows it, NJDEP may accept data obtained using direct push methods or other alternate/temporary ground water sampling techniques as part of the VI investigation. Due to the advantages listed in the above table, alternate and direct push sampling methods are often well suited for VI investigations especially if attempting to determine the depth of the interface between a shallow clean water lens and an underlying plume.

Obtaining samples that target the 0 to 3-foot and 3 to 6-foot intervals from the top of the saturated zone may be sufficient. However, as discussed above, one additional sample from the 6 to 10 foot interval bwt should be obtained where significant changes in the water table elevation are likely. Small changes of these intervals are appropriate if a sufficient volume of water can not be obtained or if site-specific data supports sampling alternate intervals. The intervals sampled should be documented and justified as part of the vapor intrusion work plan.

Direct push/alternate sampling locations should be accurately mapped and documented. The boring location should be marked, if possible, to facilitate subsequent re-sampling. Repeated sampling over time at the same locations may be necessary for some sites to determine if shallow ground water quality has changed due to water table elevation fluctuations or other factors. Ongoing monitoring recommendations are discussed below.

6.2.3.4 Monitoring Well Sampling Methods for VI Investigations

As stated in subsection 6.2.3.2, only water table wells should be used in most situations. Well sampling methods that can target the upper few feet of the screened interval (or open borehole) are recommended for gathering new data, but are not necessary in every situation in order to adequately address the VI pathway. As previously discussed, if a site's conceptual model and/or other information indicate that a vertical profile should be obtained, PDBS can be used for well sampling if appropriate as specified below.

Passive Diffusion Bag Samplers (PDBS). The NJDEP FSPM (Section 6.9.2.5.1) should be the initial source for information on PDBS.

PDBS should not be used for acetone, styrene, methyl-tert-butyl ether (MTBE), and 4-methyl-2-pentanone (MIBK). PDBS that are about 20 inches long should be used for a VI investigation. A minimum of two, but potentially three PDBS should be strung together to evaluate the vertical profile of ground water quality in the top six feet of the saturated zone. If profiling should extend to the 6 to 10 foot interval bwt, usually one PDBS deployed in the central portion of that interval

will be sufficient. This guidance differs from the vertical profiling provisions of the FSPM due to the specific VI objective of determining very shallow ground water quality.

PDBS may be deployed in a well for a minimum of two weeks to equilibrate with the well water. Significant water table fluctuations during that period will affect the appropriate depth intervals for the samplers. If the water level drops below the uppermost sampler transfer of volatiles from the sampler water into less contaminated well air space would occur. If the upper sampler is exposed to the air space, the upper sampler should be resuspended two feet below the current water level and retrieved after an additional two-week equilibration period.

As indicated in subsection 6.2.3.2, sampling that includes the 0 to 2-foot interval below the water table would provide a better indicator of the potential for VI. Where periodic water level data are available, the uppermost PDB sampler should be set within the 1 to 2-foot interval below the current water level if the historic water level data indicate it will remain submerged. Otherwise, it should be set at least 2 feet bwt. In wells where there is likely to be more significant lowering of the water level during PDBS deployment, the upper sampler should be set so that it remains submerged during the entire equilibration period. Measuring water levels in a well before and several times following significant precipitation events may help investigators anticipate the degree of fluctuation to expect. Avoid initial placement of the samplers immediately after precipitation or snow melting events, if possible. NJDEP encourages innovative approaches to allow sampling the shallowest interval while avoiding exposure of the uppermost sampler. In any event, the depth to water in the well should be measured when the PDBS are installed and removed, and the position of the samplers relative to the water level should be clearly described in the report presenting the PDBS data.

Currently, PDBS are not recommended for sampling in formations with a hydraulic conductivity of less than 1×10^{-6} cm/s because testing in such tight formations has not been conducted. In lower permeability formations, horizontal flow through the well screen would be relatively slow. Thus the rate of vapor diffusion in the well across the water/air interface may be significantly greater than the rate of off-gassing of volatiles in the adjacent formation across the saturated zone/vadose zone interface. This may cause a low concentration bias for diffusion bags placed in

the shallowest interval. If the uppermost sampler is placed 2 feet below the current water level, this bias would likely be negligible. However, if the sampler is placed within the 0 to 2 foot interval, placement of a contaminant free, floating, partial plug designed to minimize off gassing may be proposed for VI investigations in low permeability settings.

In some instances, vertical flow can be present within the well. Site-specific guidance from NJDEP should be obtained in this situation but it may be possible to place packers between the PDBS to isolate the targeted depth interval.

Low Flow Purging and Sampling (LFPS). Unless vertical contaminant profiling is recommended, the LFPS procedures in the NJDEP Field Sampling Procedures Manual (2005) is acceptable for VI investigations if the vertical thickness of the water column in the well is 10 feet or less.

If evaluating the VI pathway is the only sampling objective, NJDEP recommends two modifications to the LFPS procedure.

- Set the pump intake level as close to the water table as possible without significant risk that the water level will drop and expose the pump intake. For wells in formations with average or high permeability, about 1.5 to 2 feet below the static water level should be an adequate intake location.
- The purging objective is to flush two volumes of ground water through the sampling array (tubing and pump, etc.). Measuring water quality indicator parameters is not necessary.

These two deviations from procedures recommended in the NJDEP's guidance apply only to new sampling done exclusively for a VI investigation. In some hydrogeological settings these modifications may result in more of the sampled water coming from the interval just below the water table (Vroblesky 2001). The resulting sample would still represent a weighted average and may draw water from the entire screened interval of the well, but these modifications help maximize the probability that much of the sample will be from a depth interval close to the depth of the pump intake.

If sampling is being done for multiple objectives, only the procedures in the NJDEP FSPM should be followed.

Other Discrete Interval Well Sampling Methods. Other discrete interval well sampling devices or methods (such as use of packers between PDBS) may be considered on a site-specific basis according to N.J.A.C. 7:26E-4.4(d) and 1.6(c). Use of such methods without prior NJDEP approval is not recommended since at risk sampling of this nature may result in the data being considered invalid by NJDEP. For general NJDEP policy on Point Source (No Purge) Sampling, refer to the FSPM, Section 6.9.2.5.

Volume-Averaged Purge and Sample Collection. This method is not recommended when obtaining new data specifically geared for a VI investigation.

6.2.3.5 Installation of New Monitor Wells

If the investigator determines new wells are needed to evaluate the VI Pathway, the following guidance is provided. In New Jersey, fluctuations in the short-term water table elevation between 1 to 3 feet appear to be fairly common. Larger changes have also been observed across the state over seasonal and longer time frames in various geologic settings. Site-specific data quality objectives (DQO) and information should be used in choosing well construction specifications.

In unconsolidated formations, monitoring wells should be screened across the water table. Two crucial well design objectives are: ensuring that the well is screened across the water table throughout the expected monitoring time frame; and minimizing saturated screen length with respect to historical high and low water table events for the immediate area of concern. If little water table elevation data are available, consider whether the water table is likely to rise or fall after the time of well design/installation. Screen lengths between 5 and 10 feet are preferred for evaluating VI. However, screen lengths of 15 feet, placed such that the total depth of the water

column will be approximately 10 feet or less (i.e., 5 or more feet of screen above the water table) are more appropriate for wells designed for multiple DQOs.

If bedrock wells are installed as part of a VI investigation, open hole intervals should generally be 10 feet or less and should target the most shallow water bearing zone. In highly weathered/fractured bedrock formations, shallow ground water flow and contaminant migration can exhibit patterns more typical of unconsolidated formations. In those situations, local heterogeneity of the bedrock may not have as much influence on whether volatiles in ground water can off-gas into the vadose zone and diffuse up to structures at the surface. Therefore, construction of monitoring wells in such settings can be a part of a VI investigation.

Where consolidated, competent, heterogeneous bedrock aquifers contain the uppermost water bearing zones, monitor well installation and ground water sampling are not considered the most reliable approach for a VI investigation, nor are they practical or cost-effective. Sub-slab (or possibly near slab) soil gas sampling is recommended in such complex geologic settings.

It is not uncommon that the water table, or a perched water table, is located within the transition zone between unconsolidated overburden and a consolidated formation or competent bedrock. Constructing a well to monitor the top few feet of the saturated zone in such a setting requires approval of a deviation from the regulations governing monitoring well construction at N.J.A.C. 7:9D-2.1 et al. New Jersey licensed well drillers must request a deviation from the construction standards as specified at N.J.A.C. 7:9D-2.8. Discussion with, and approval from, the NJDEP case manager is recommended prior to requesting such a deviation from the well construction regulations.

6.2.3.6 Ongoing Ground Water Monitoring

After an initial VI investigation has been completed, long term ground water monitoring to reevaluate the VI pathway may be appropriate in some situations although monitoring other media can potentially substitute for ground water monitoring. Ground water monitoring should be done where ground water exceeding the GWSL is close to, but not currently within the

applicable distance criterion from a potential structure if it is likely to migrate to within the distance criterion.

Installing a monitoring well or wells near the structure(s) may be the best way to monitor whether water levels and/or ground water quality have changed in a way that warrants additional investigation. Direct push or alternate ground water sampling methods could also potentially be utilized and may be a good choice where vertical contaminant profiling is recommended but a low sampling frequency is appropriate. Additional guidance concerning ongoing monitoring can be found in Section 7.3.

Ground water remedial action workplans for sites where a VI investigation was conducted should include at least a periodic evaluation of whether any changes in site conditions have increased the risk of VI.

6.3 Exterior or Near Slab Soil Gas Sampling Procedures

One of the most common methods for assessing the VI pathway is the collection of exterior or near slab soil gas samples.

The distinction between exterior and near slab soil gas sampling is critical for the investigation of the VI pathway. While both procedures involve the collection of soil gas samples outside a structure, near slab specifically refers to the collection of soil gas samples within 10 feet horizontally of a building's foundation. Conversely, exterior soil gas samples are collected beyond the 10-foot perimeter surrounding the building footprint. The applicability of the soil gas results is significantly different from the Department's perspective (see below). Therefore, the distinction between near slab and exterior soil gas sampling is important.

6.3.1 Application

Exterior and near slab soil gas sampling can be useful to an environmental investigator from several perspectives.

6.3.1.1 Stand-Alone assessment of the VI pathway (Near Slab Only)

In general, exterior soil gas sampling is not acceptable as the exclusive determinant in the assessment of the VI pathway. The Department's preference is for the collection of sub-slab over near slab soil gas samples. The investigator should make every effort to obtain soil gas data from below the slab. However, the cooperation of the building occupants and/or owners is not guaranteed. They are often reluctant to allow someone to drill a hole in the basement slab, especially if it's a finished basement. Thus, near slab soil gas sampling becomes an alternative to sub-slab sampling when situations dictate a supplementary approach.

Analytical results from near slab soil gas sampling may be utilized (with the Department's approval) to determine whether the VI pathway is currently complete for a particular building. However, the Department does **not** accept the results from exterior soil gas sampling as a stand-alone factor in the assessment of the VI pathway. Concerns over false negative results (due to soil types, soil moisture, etc.) make exterior soil gas data more appropriate as a field screening tool.

Many of the same factors that make exterior soil gas sampling inappropriate as a stand-alone determination of VI also apply to some extent to near slab soil gas sampling. Therefore, the Department should approve the utilization of near slab soil gas sampling in advance of the sampling event. Justification shall be provided to the Department as to why the sub-slab soil gas sampling method is not feasible.

In order for the near slab soil gas results to be acceptable to the Department in any stand-alone assessment of the VI pathway, the following criteria must be met:

- The soil gas samples should be collected at the depth corresponding to the range between 2 feet and 5 feet below the depth of the slab (and a minimum of 5 feet below the ground surface);
- The soil gas sample should be collected in the vadose zone, at least one foot above the capillary fringe;

- Soil gas samples should be collected at a minimum from two sides of the building being investigated (biased towards the delineated ground water plume or soil contaminant source);
- All sampling procedures provided in this guidance and the NJDEP's Field Sampling Procedures Manual (latest edition) should be followed for the collection of soil gas samples; and
- A lab certified for an appropriate air method must analyze the samples (USEPA Method TO-15 using 1-Liter or 6-Liter stainless steel canisters is the most common method).

As with sub-slab soil gas sampling, it is important to understand the stratigraphy in the area of the building. Low permeability layers under buildings (either natural or as part of construction) may act as an impediment to significant vertical vapor migration from the ground water contamination. The presence of such a layer may explain why random or irregular soil gas results occur when comparing data from several sample locations around a building. The soil gas results may not be consistent with the concentrations found in the underlying ground water plume. Always refer back to the CSM when evaluating data and making any conclusions on the VI pathway.

The Department does not allow the results of the soil gas samples to be averaged across the subsurface around a building. Therefore, each data point should be evaluated independently of each other.

6.3.1.2 Field screening

Exterior soil gas sampling is a screening tool used to rapidly and cost effectively identify and delineate volatiles in the subsurface. It should be noted that a soil gas survey is not intended to be a substitute for conventional methodology (e.g., ground water sampling), but instead as a screening tool to enable conventional methods to be used more effectively. A certified mobile laboratory may be utilized as part of this investigation.

6.3.1.3 Evaluating contaminant patterns

Analytical data from near slab (and to a lesser extent exterior) soil gas samples should be assessed to identify any patterns in particular chemicals, groups of chemicals, and/or their concentrations (both individually and collectively). When combined with data from other matrices (e.g., ground water, indoor air, and ambient air), these patterns may assist in distinguishing likely sources of indoor air contaminants and their pathways. This is important when background sources located within the structure generate the same volatile organic compounds identified as contaminants of concern associated with the site investigation.

6.3.1.4 Assessing background contamination

Similar to sub-slab soil gas samples, one specific area where near slab (and to a lesser extent exterior) soil gas results are useful is in the differentiation of background contamination in indoor air. By comparing the specific chemicals detected in the soil gas sample with the ground water or soil contaminants associated with the site investigation, a verification of the contaminants of concern can be made. This determination validates the designation of background contaminants and thus limits any remedial action to site related contaminants.

6.3.2 Sampling Procedure

6.3.2.1 Site Conditions

The first step in conducting a soil gas investigation is to determine the site conditions.

According to the NJDEP Field Sampling Procedures Manual (2005), one of the most important factors in the movement of vapors through soil is the soil permeability. The soil permeability is the measure of the ease at which a gas or liquid can move through rock, soil or sediment. Soil permeability is related to the grain size and the amount of water in the soil. Soils with smaller grain sizes are less permeable unless secondary porosity (e.g., fractured clays) increases permeability. When soils contain clay size particles, soil gas movement is severely limited. If the

soils are poorly sorted with increased fine grained material content, the pore space is decreased. The presence of moisture in the soil decreases the rate of vapor migration. This occurs because as the volume of soil water increases, the soil airspace decreases thereby inhibiting vapor movement. The most retarding layer will dictate the rate of diffusion of vapors in the vadose zone.

Heterogeneous soil conditions across a site under investigation can lead to poor delineation and misinterpretation of site contaminants due to the interference from the different soil conditions. Data from areas of horizontal low permeability zones within the vadose zone could be interpreted as being an area of low contamination, when the level of contamination could be the same or higher. Conversely, data from an area of high permeability in an otherwise low permeability area can be interpreted as an area of high contamination. High porosity areas such as sewer and utility trenches can serve as conduits for rapid vapor or gas migration, giving a false indication of high contamination areas. In situations where little or no soil data is available, several soil borings should be logged to aid in the interpretation of the generated soil gas data.

The investigator should properly determine the site conditions as part of any VI investigative workplan.

6.3.2.2 Soil Gas Sampling

Active soil gas collection methods involve “pulling” a vapor sample through a temporary or permanent probe to a collection or analytical device. Samples are then transported to a laboratory for analysis or analyzed onsite so real time data can be obtained and used for directing the investigation.

Manually or hydraulically driven soil vapor probes should be constructed of steel and equipped with a hardened drop-off or retractable steel tip. The probes are nominally 3-5 feet long and threaded together to reach multiple depths. The probe is used for obtaining soil gas samples at discrete depths with few failures due to hole clogging. A small diameter inert tube can be

inserted through the center of the rod and connected to the drive point (Hartman 2004). When the probe is retracted or pulled up, the probe is "open" for soil gas sampling.

In general, soil gas sampling events should be avoided after sizeable rainfall.

Exterior and near slab soil gas samples should be collected at a minimum depth of 5 feet below the ground surface. In situations where the ground water table is less than 5 feet, alternative sampling protocols may have to be employed. The investigator may propose collecting soil gas samples from below existing large impervious surfaces where vapor accumulation may occur, including garage floors, patios, parking lots, roads and driveways. Approval for alternative approaches to the 5-foot depth provision should be requested in advance from the Department.

6.3.2.3 *Annular Seal and Tracer Gas*

The annular seal is maintained by the soil against the probe rods. Therefore the drive tip cannot be larger than the probe rods or there will be no annular seal provided when the probe is pulled back to open the probe. Probes or rods, which have an irregular shape, will not allow for a competent seal and can lead to sample dilution and erroneous results.

To verify the integrity of the seal, the investigator should utilize a tracer compound, typically iso-propanol, butane, helium, sulfur hexafluoride, or difluoroethane. The tracer is placed around the base of the probe and at the various connections in the sampling system prior to sample collection. Liquid tracers are easily employed by wetting a paper towel and wrapping it around the test locations (Hartman 2004). The presence of the tracer compound in the analysis (generally in excess of 1,000 µg/L) confirms a leak and another sample should be collected until no leak is detected.

Another method employs a shroud or plastic sheeting placed around the sample probe. An inert tracer gas (such as helium) is released under the sheeting. The initial soil gas samples (after purging) can be monitored using field-screening instruments for elevated concentrations (>5%).

of the tracer gas (based on the original tracer gas concentration in the shroud). Tracer gases are discussed in more detail in the State of New York draft guidance document (NYDOH 2005).

Multiple insertions of the drive rods into a single hole during depth profiling will result in too much “play” in the rods and will not provide a competent annular seal. Therefore, a new hole is required for each sample point.

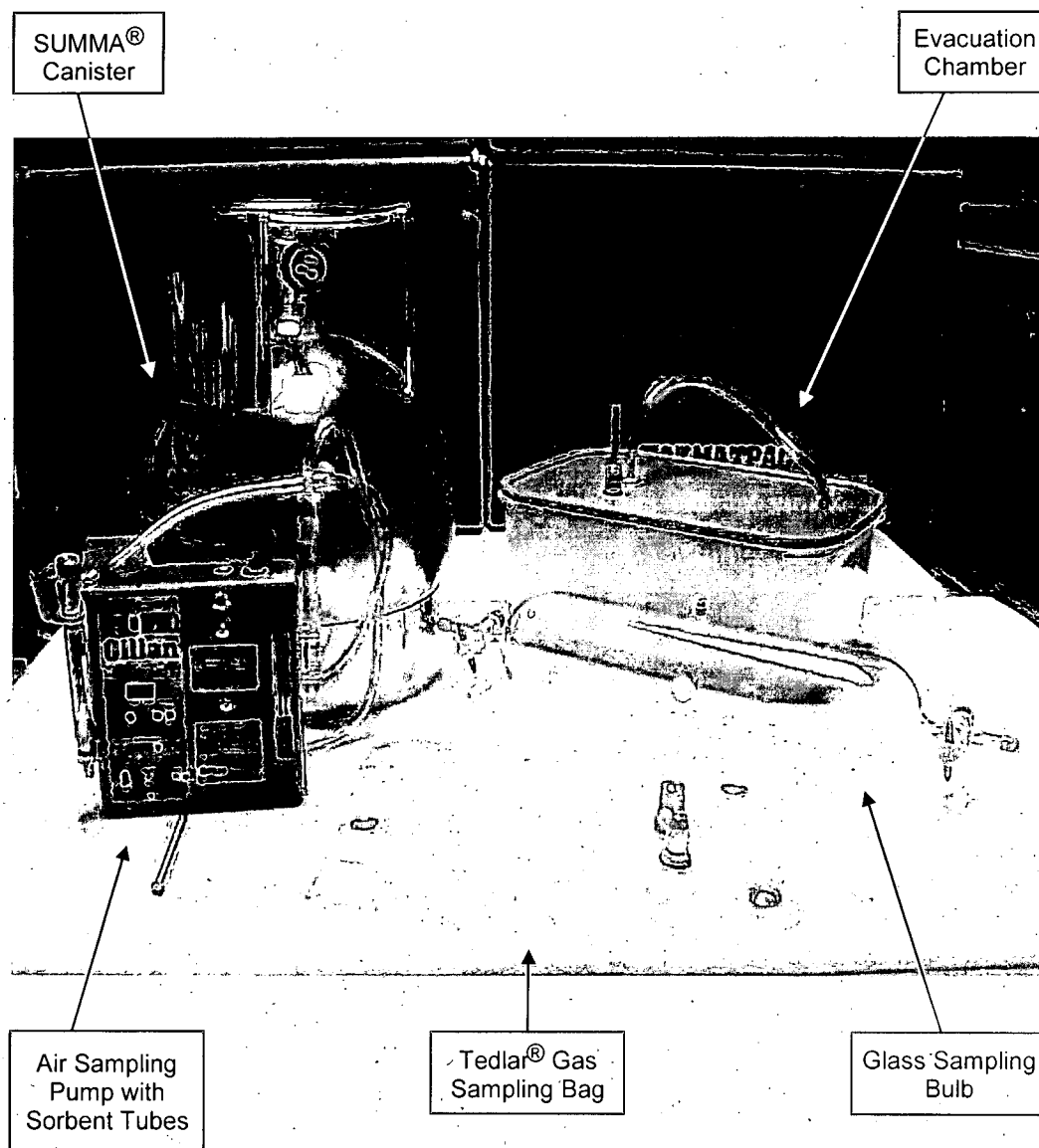
Depending on the circumstances, permanent soil gas probes may be employed. Permanent soil gas probes are constructed so soil gas samples can be obtained from the same location over time. They are used to obtain data on changes in soil gas concentrations over time. Single or multiple probes may be installed into a single borehole to obtain vertical profile data. Permanent probes are recommended for projects requiring more than one soil gas sampling event to monitor subsurface gas conditions for gas migration control or to monitor remediation activities. Please refer to the NJDEP Field Sampling Procedures Manual (2005) for additional information on permanent soil gas probes.

6.3.2.4 Sample Containers and Analytical Methods

The primary sample container recommended for the collection of near slab or exterior soil gas samples is stainless steel canisters. Either 1-Liter or 6-Liter canisters may be employed. However, the Department recommends that smaller sample containers be utilized for soil gas sampling to avoid short-circuiting or dilution of the sample with atmospheric air. The sub-slab soil gas samples shall be analyzed using USEPA Method TO-15 when stainless steel canisters are employed.

Sample containers other than stainless steel canisters can be employed when screening or preliminary results are appropriate. The investigator can utilize a gas sample bag (Tedlar®, Teflon®, metal-coated Tedlar®, etc.) with an evacuation chamber. The use of an evacuation

AIR SAMPLING EQUIPMENT



chamber allows an air sample to be collected without the sample passing through a pump. Samples collected in gas sample bags are analyzed with a field GC or mobile laboratory.

Consistent with the NJDEP Field Sampling Procedures Manual (2005), the holding time for Tedlar bags should not exceed 3 hours.

Alternately, syringes can be used to withdraw a soil gas sample from a probe and then the sample is immediately injected directly into an analytical instrument for onsite analysis. Syringes come in varying volumes, materials of construction and designs to meet the analytical criteria. Syringe samples should be analyzed with a field GC or mobile laboratory and they have a short holding time (minutes).

A less common sample container is a glass cylinder or sampling bulb which has openings at each end and with a septum port to withdraw sample aliquots with a syringe. The air sample is collected by connecting one end of the bulb to the probe and the other to a pump. Sample holding times for the glass bulbs is 24 hours (NJDEP, 2005).

The analytical method used for the alternative sample containers is not stipulated in this guidance. However, USEPA SW-846 Method 8260B is the most common method utilized for field screening of soil gas samples.

If the purpose of the near slab soil gas sampling is as a stand-alone assessment of the VI pathway, a certified laboratory must be employed. At this time, that would require the use of 1-Liter or 6-Liter canister samples analyzed with USEPA Method TO-15.

The Department may entertain the utilization of a mobile laboratory certified in an appropriate air method as a stand-alone assessment. However, detection limits shall meet the NJDEP SGSL. In addition, 10% of the air samples should be collected as duplicates using stainless steel canisters and analyzed at a fixed laboratory for USEPA Method TO-15. The duplicate samples should be collected from locations containing a range of volatile concentrations.

The initial rounds of soil gas samples should be analyzed for the full suite of volatiles based on the approved method. Subsequent phases of soil gas sampling can employ a reduced parameter list as part of an approved VI investigation workplan.

6.3.2.5 *Purge Volumes*

Prior to attaching the sample container, the vapor probe should be purged by drawing 3.0 volumes of air through the probe and connecting tubing. The volume is calculated as follows:

$$PurgeVolume = 3.0\pi r^2 h$$

where r is the inner radius of the probe and connecting tubing, and h is the length of the probe and connecting tubing. The investigator should use a low purge rate at a maximum of 200 ml per minute (based on professional judgment).

Alternately, the vapor probe or soil gas well can be purged until field-screening parameters are stabilized. This approach typically employs 3-Liter Tedlar bags and a lung box to collect the purged air samples, which are then analyzed for O_2 , CO_2 , and PID/FID readings. The investigator should avoid excessive purging of the subsurface environment.

6.3.2.6 *Sample Flow Rate*

When a gas sample bag or syringe is utilized in combination with a field GC or mobile laboratory, the length of time for sample collection should be a maximum of 200 milliliters per minute (based on the professional judgment of the investigator). Care should be taken to avoid short circuiting or drawing in outside air along preferential pathways. Thus, instantaneous or grab samples are not acceptable due to the increased possibility of short circuiting leading to an invalid sample.

For stainless steel canisters, the sample flow rate should be a maximum of 200 milliliters per minute, which corresponds to a sample time of 5 minutes for 1-Liter canisters. This maximum flow rate has been established due to the larger volume of stainless steel canisters and the concern over short-circuiting.

The certified laboratory provides stainless steel canisters with pre-set regulators (based on the sample time prescribed by the investigator). Therefore, the sample time must be established in

advance of the sampling event. Investigators can determine a draw rate prior to the soil gas sampling event through the installation of a test probe and subsequent draw rate determination with a purge pump.

6.3.2.7 *Sample Locations*

If near slab soil gas samples are being collected as a stand-alone assessment of the VI pathway, samples should be collected from at least two sides of the building in question. Precise locations will be in part dictated by the existing conditions around the building perimeter (e.g., other structures, landscaping, access issues) and the precise location of the ground water plume. The VI investigation workplan shall identify specific sample locations and provide technical justification for their selection.

Conversely, if the purpose of the soil gas sampling event is for any other purpose including field screening, the sample locations should be determined based on the end use of the data. The VI investigation workplan should define the goal of the soil gas sampling approach and how the proposed locations meet that need.

6.3.2.8 *Number of Samples*

In general, the number of samples recommended for the VI investigation is dictated by the sample spacing necessary. Samples should be spaced horizontally at a minimum of two to three times the depth to ground water. For a typical single family dwelling of 1,500 ft², one sample on each of two sides would be a minimum number of near slab soil gas samples. However, larger multi-family residential units and commercial, industrial or retail buildings may require additional samples spaced equidistant from each other (consistent with the depth to water table rule above).

If two soil gas sample locations have two to three orders of magnitude difference in concentration, at least one sample should be collected between the two points. Reducing the sample intervals below this distance across a site will not necessarily provide for better

resolution of contamination. It may only indicate the variability in the soil horizon rather than changes in volatile concentrations. Soil gas sampling is not a high resolution technique for contamination delineation and should not be used for this type of interpretation (NJDEP Field Sampling Procedures Manual 2005).

Any decision on the number of soil gas sample points should start with an evaluation of the CSM. If there are indications from the ground water characterization that there could be large lateral changes in concentrations over short distances near a structure, there may be a case for increasing the number of sample points.

6.3.2.9 Sample Frequency

As discussed in Chapter 6.6 (Indoor Air Sampling Procedures), seasonal variability in vapor concentrations necessitates (in most circumstances) collecting more than one round of indoor air samples. Similar variability is not apparent in soil gas samples. However, if near slab soil gas samples are being collected as a stand-alone determination of the VI pathway, a second confirmation sample may be necessary.

The Department recommends the collection of sub-slab soil gas samples whenever indoor air samples are obtained. Therefore, multiple rounds of sub-slab soil gas samples may be dictated by the sampling requirements of indoor air. For indoor air, one of the two sampling events should take place during the months between November and March, since these are generally “worst case” conditions for VI (see Chapter 6.6, Indoor Air Sampling Procedures).

In situations where near slab or exterior soil gas sampling is being done to evaluate contaminant patterns or assess background contamination, a decision on the frequency of sampling should be determined on a site-specific basis.

6.3.2.10 Underground Utilities

Many accidents in subsurface investigations are due to encountering subsurface utilities. Prior to mobilizing for any soil gas investigation, health and safety concerns must be answered. Of

greatest concern would be to locate any underground utilities. NJ One Call is a free service and can be contacted at 1-800-272-1000 (out of State call 908-232-1232). They will contact all utility companies that may have services in the area of investigation. Calls must not be made less than 3 full working days and not more than 10 working days prior to the planned work. If work is delayed past the 10 days, you are required to renew your ticket. "One Call" legislation mandates that all owners of underground infrastructures become New Jersey One Call members.

6.3.2.11 License Requirements

The license requirement for performing a soil gas survey is for the installation of the soil gas probes used for the collection of a soil gas sample. The requirement is based on depth and diameter of the boring and the length of time a probe will remain in the hole. Please consult N.J.A.C. 7:9D-*Well Construction; Maintenance and Sealing of Abandoned Wells* for further information. A copy is available through the Bureau of Water Allocation 609-984-6831.

6.3.2.12 Passive Sample Collection Methodologies

According to the NJDEP Field Sampling Procedures Manual (NJDEP 2005), Passive sample collection includes two general sample collection techniques. These techniques include the passive collection of contaminants onto sorbent material placed in the vadose zone and a whole air passive collection technique for collecting vapors emissions from the soil surface using an emission isolation flux chamber.

Passive sorbent sample collection utilizes diffusion and adsorption for soil gas collection onto a sorbent collection device over time. The soil gas data will delineate the nature and extent of subsurface contamination. The soil gas data at one location can be compared relative to the soil gas data from other sample locations in the survey. The mass levels will show patterns of the spatial distribution indicating areas of greatest subsurface impact. These areas can then be targeted for further investigation.

Since the passive sorbent samplers provide results in mass concentration, their use is limited to field screening only during the investigation of the VI pathway.

The flux chamber is an enclosure device used to sample gaseous emissions from a defined surface area. These data can be used to develop emission rates for a given source for predictive modeling of population exposure assessments. The data can also be used to develop emission factors for remedial action designs.

The emission isolation flux chamber is a dome superimposed on a cylinder. This shape provides efficient mixing since no corners are present and thereby minimizing dead spaces. Clean dry sweep air is added to the chamber at a controlled volumetric flow rate. The gaseous emissions are swept through the exit port where the concentration is monitored by a real time or discrete analyzer. Real time measurements are typically performed with portable survey instruments to determine relative measurements of flux chamber steady state operation and hot zones. Discrete samples are taken when absolute measurements are required for steady state concentrations and emission rate levels. The emission rate is calculated based upon the surface area isolated, sweep airflow rate, and the gas concentration. An estimated average emission rate for the source area is calculated based upon statistical or biased sampling of a defined total area.

The approval to utilize flux chamber sampling should be requested from the Department in advance of the sampling event as part of a Site-Specific Assessment (Stage 6). Justification should be provided to the Department as to why the emission isolation flux chamber method is more appropriate for this particular phase of the investigation.

6.3.2.13 Undeveloped Parcels and Future Use

When the potential for VI extends to undeveloped parcels, a VI investigation must be implemented to assess the impact on future use. A generic approach to investigating an undeveloped parcel would be conducting soil gas sampling on a 100-foot grid at a minimum depth of 5 feet. This grid method is approximately equal to the average New Jersey residential housing tract of $\frac{1}{4}$ acres. In situations where the future use is restricted by an institutional control, an alternative approach may be proposed, possibly postponing investigation to some point in the future when development is being considered.

6.3.2.14 Data Evaluation

Near slab soil gas results are generally utilized for comparison to other data sets (e.g., ground water, indoor air, and ambient air). For the most part, these data allow the investigator to determine patterns in the results and differentiate site-related compounds from other potential sources. Like sub-slab results, near slab soil gas data can be compared to the NJDEP SGSL.

6.4 Sub-Slab Soil Gas Sampling Procedures

The collection of sub-slab soil gas is an effective investigative tool when assessing the VI pathway. The procedure involves drilling through the building's concrete slab and collecting a soil gas sample for field or laboratory analysis. Sub-slab soil gas samples are often collected concurrently with indoor air samples to assess VI and potential background contaminant sources.

In situations where an earthen floor exists (instead of concrete), the provisions for sub-slab soil gas sampling may not be appropriate. Structures are often built with partial or full crawl spaces that extend the entire building footprint and utilize gravel or dirt. In other situations, the basement may be unfinished without a concrete floor. As a general rule, sub-slab soil gas sampling should be employed when the basement slab covers 50% or more of the building footprint. In these situations, it may be prudent to collect a combination of sub-slab soil gas samples from the concrete area and indoor air samples from the crawl space.

It is also important to understand the differences between sub-slab and exterior soil gas sampling. Sub-slab refers to soil gas samples collected from below a slab (typically in the basement of a building). Exterior, on the other hand, involves collecting soil gas samples from below the ground surface outside of a structure, utilizing a Geoprobe or slam bar. The soil gas samples collected from the earthen areas should be collected according to the procedures for near slab or exterior soil gas sampling found in Chapter 6.3 (Exterior and Near Slab Soil Gas Sampling Procedures).

The utilization of sub-slab soil gas sampling is also questionable when a high water table exists near the base of the sub-floor (less than 2 feet). Typically, vapors migrate through the most coarse and/or driest material. Depending on the analytical method, high moisture content in the soil gas sample can "mask" results, particularly polar compounds. Additionally, reduced permeability of the soil in the capillary fringe area may limit the movement of soil gas.

Specifically, sub-slab soil gas samples can be collected when ground water is as close as two feet below the building foundation if:

- 1) The seasonal high water table does not reach the building foundation; and
- 2) The water table does not extend into fill material directly under the building foundation; and
- 3) The capillary zone does not reach the building foundation.

The Department may be consulted for additional information in these situations.

6.4.1 Application

Sub-slab soil gas sampling can be useful to an environmental investigator from several perspectives.

6.4.1.1 Stand-Alone Assessment of the VI Pathway

Under the right circumstances, the results of sub-slab soil gas sampling may be utilized to determine whether the VI pathway is currently complete for a particular building. This is appropriate when the source of the vapors is a contaminated ground water plume under or in close proximity to the building in question. Investigators may want to collect sub-slab soil gas samples as an alternative to indoor air sampling in situations where indoor sources are likely to significantly affect indoor air quality.

While the Department recognizes the role of sub-slab soil gas sampling in assessing the VI pathway, there are a number of factors that have to be considered when utilizing these data. Sub-

slab soil gas is not as likely to be definitive when the vapor source is solely subsurface contaminated soil (vadose zone). For example, there may be situations where vapors migrate laterally and do not collect under the building's slab (depending on the building construction, the depth of the soil contamination, and the slab's depth below the surface). In addition, preferential pathways, such as utility trenches, allow horizontal movement of the vapors. In these cases, infiltration of vapors through openings in the sidewalls of a basement may represent the primary pathway for VI. As a result, sub-slab soil gas results may be low or marginal, while indoor air data can still exceed health-based levels. Under these conditions, near slab soil gas samples collected between the zone of soil contamination and the structure's foundation may be more appropriate than sub-slab samples.

It is important to understand the stratigraphy in the area of the building. Low permeability layers under buildings (either natural or as part of construction) may act as an impediment to significant vertical vapor migration from the ground water contamination. The presence of such a layer may explain why relatively clean sub-slab samples can occur even though underlying ground water is contaminated. However, vapors may still enter the building through utility trenches or other preferential pathways if they bisect or circumvent the low permeability layer.

The presence of elevated contaminant vapors in the sub-slab soil gas is generally a positive indicator of VI when applying an attenuation factor (discussed below). However, the reverse circumstances (low contaminated levels in the sub-slab soil gas) do not automatically imply that the vapor pathway is incomplete. Site-specific conditions, such as distance from any vadose zone sources and depth of those sources (see the CSM section) should be evaluated before reaching any conclusions on the VI pathway.

6.4.1.2 Evaluating Contaminant Patterns

Analytical data from sub-slab soil gas samples should be assessed to identify any patterns in particular chemicals, groups of chemicals and/or their concentrations (both individually and collectively). When combined with data from other matrices (e.g., ground water, indoor air, and ambient air), these patterns may assist in distinguishing likely sources of indoor air contaminants

and their pathways. For a further discussion on this topic, see Chapter 7, Evaluation of Analytical Results and Risk.

In addition, the investigator may want to evaluate the vertical depth profile of the contaminated soil gas. Vertical profiling is considered a site-specific procedure (see Chapter 5 for more information).

6.4.1.3 Assessing Background Contamination

One specific area where sub-slab soil gas results are particularly useful is in the differentiation of background contamination in indoor air. By comparing the specific chemicals (and their concentrations) detected in the indoor air sample with the sub-slab soil gas sample, a determination may be possible on the likely role of background sources. In addition, the end user should consider the horizontal movement of vapors as a potential contributor to the indoor air quality (as discussed in Section 6.4.1.1, above).

6.4.2 Sampling Procedure

Two different basic procedures for sub-slab soil gas sampling are provided below.

The first method employs a permanent sample point with stainless steel tubing and fittings. This method is recommended for long term monitoring of sub-slab soil gas as part of a remedial action. The approved Remedial Action Workplan shall include a VI monitoring plan to assess the changing concentration of contaminants of concern over time. Any decision to terminate a remedial action involving VI will most likely be made in part based on the sub-slab soil gas results.

The second procedure utilizes Teflon, metal (or similar) tubing for a temporary sample point. This method is more appropriate during the initial phases of investigation when the VI pathway is being evaluated. However, the investigator may want to use permanent sample points as part of the remedial investigation.

Alternative procedures for the collection of sub-slab soil gas samples should be submitted and approved by the Department in advance of the field activities.

Irrespective of the sampling method, the investigator should provide a detailed description of the site-specific conditions, including the type of sub-slab soil and backfill, the presence/absence of water, and the thickness of flooring (tile, concrete, etc.).

The general condition of the slab and walls should be documented as part of the Building Survey form (which should be filled out during all sub-slab soil gas sampling events). The investigator should note the presence of sumps, cleanouts and floor drains.

In addition, the sub-slab sampling points should be installed in such a manner so as to provide a tight seal around the sampling point which serves to isolate the sub-slab environment from the inside of the building and allow for collection of samples which are representative of sub-slab vapor conditions.

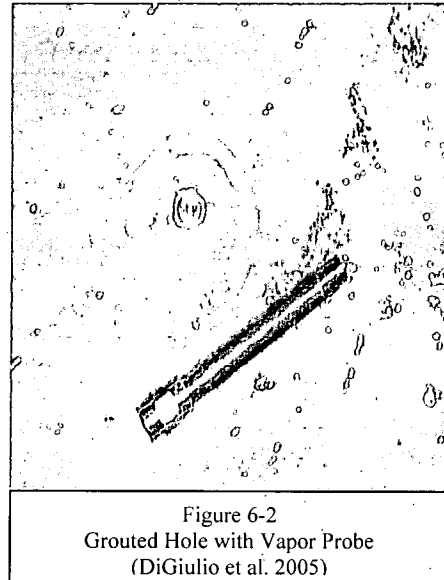


Figure 6-2
Grouted Hole with Vapor Probe
(DiGiulio et al. 2005)

One note of caution: Be aware of the subsurface conditions under the slab before you drill. What is the depth to the high water table? Are underground utilities (e.g., electric, gas, water or sewer lines) located below the slab? You don't want to create a preferential pathway for ground water to move into the living space. Also, question the occupants about whether a vapor barrier may already exist under the slab. Avoid puncturing the vapor barrier unless you are equipped to repair it afterwards. When a vapor barrier is present under the slab, the investigator should consider installing a leak-free permanent sampling probe.

6.4.2.1 *Permanent Sample Point Approach*

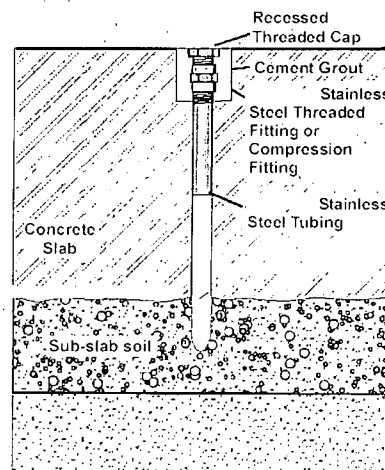
- Remove carpeting, if present (this may require cutting a small ½" square flap that can be glued back down after the sampling event is completed).

- Drill a 3/8" diameter hole through the concrete slab using an electric drill.
- Advance the drill bit approximately 3" into the subslab material (gravel or soil) to create an open cavity.
- Overdrill the top 1" (vertical) of the probe hole to a diameter of 1".
- Insert the vapor probe flush with the top of the concrete slab and add a non-volatile emitting surface sealing material (e.g., portland cement) to seal the annular space.
- Allow the test points to cure for at least 1 hour (portland cement will likely take longer).
- Connect the vapor probe to a "T" fitting made of a stainless steel flexible line (or similar inert material) and an in-line valve.
- Purge the vapor probes and sampling lines (see discussion below on purge volumes).
- Close valve on the vacuum pump line.
- Open the valve to collect a sub-slab soil gas sample.

A typical vapor probe is constructed from small diameter (e.g., 0.64 cm or 1/4 in OD x 0.46 cm or 0.18 in ID) chromatography grade 316 stainless steel tubing and stainless steel compression to thread fittings (e.g., 0.64 cm or 1/4 in OD x 0.32 cm or 1/8 in NPT Swagelok female thread connectors) (DiGiulio et al. 2005). It is imperative that the vapor probe is completed flush with the concrete surface to avoid problems for the occupants of the building. It should be noted that the dimensions of the vapor probe and the corresponding hole, as well as the materials utilized in the sampling apparatus, are guides and are not suppose to be prescriptive. Minor modifications may be appropriate. Alternative methods utilizing established protocols (e.g., ASTM) may be considered.

Ideally, the vapor probes should remain in the concrete slab beyond their initial use. It may be necessary to collect additional rounds of sub-slab soil gas to properly assess the VI pathway. Furthermore, the vapor probes may assist with any potential remedial actions

Figure 6-3
General
Schematic for
Installation of
Sub-Slab
Vapor Probes
(DiGiulio et al., 2005)



involving sub-slab depressurization systems. The building owners should be encouraged to allow the vapor probes to remain in place for the foreseeable future.

6.4.2.2 Temporary Sample Point Approach

Depending on the particular circumstances (e.g., occupant's preferences, early investigative phase, and urgency of sample collection), a temporary or less permanent probe may be utilized. Instead of the stainless steel tubing and fittings, 1/8 to 3/8 in tubing (Teflon, nylaflow, metal or similar materials) may be substituted. The tubing should be wrapped with Teflon tape to create a snug fit when the tubing is twisted into the hole. The drill hole should be smooth wall to minimize potential for leaks. Modeling clay, beeswax or other non-volatile emitting and non-shrinking materials may be utilized.

The objective with a temporary sample point is to use tubing that is only slightly smaller in diameter than the drill hole. Do NOT overdrill the top 1" (vertical) of the probe hole – as with a permanent sample point. Since portland cement is not being used, the sample points can be set up the same day as the sub-slab soil gas sampling (Hers and Rees 2005). Purging and sample collection (with a stainless steel canister) should be conducted similarly to the permanent sample point procedures above.

6.4.2.3 Sample Containers and Analytical Methods

The primary sample container recommended for the collection of sub-slab soil gas samples is stainless steel canisters. Either 1-Liter or 6-Liter canisters may be employed. The sub-slab soil gas samples should be analyzed using USEPA Method TO-15 (or other appropriate certified methods).

Sample containers other than stainless steel canisters can be employed when screening or preliminary results are appropriate. The investigator can utilize a Tedlar bag for sample collection and analyze the samples with a field GC or mobile laboratory. Alternately, a 60 - 500 cubic centimeter (cc) syringe can be used. As with the Tedlar bags, syringe samples should be

analyzed with a field GC or mobile laboratory. It should be noted that the holding time for Tedlar bags should not exceed 3 hours.

The analytical method used for the alternative sample containers is not stipulated in this guidance. However, USEPA SW-846 Method 8260B is the most common method utilized for field screening of air samples.

If the purpose of the sub-slab soil gas sampling is as a stand-alone assessment of the VI pathway, a certified laboratory using USEPA Method TO-15 or TO-17 must be employed.

6.4.2.4 Sample Flow Rate

When a Tedlar bag or syringe is utilized in combination with a field GC or mobile laboratory, the length of time for sample collection should be a maximum of 200 milliliters per minute (based on the professional judgment of the investigator). Care should be taken to avoid short circuiting or drawing in outside air along preferential pathways. In addition, a proper seal between the sample point and slab must be established to prevent indoor air from mixing with the soil gas sample. For these reasons, instantaneous or grab samples are not acceptable.

For stainless steel canisters, the sample flow rate should be a maximum of 200 milliliters per minute, which corresponds to a sample time of 5 minutes for 1-Liter canisters. This maximum flow rate has been established due to the larger volume of stainless steel canisters and the concern over short circuiting. The investigator may want to collect the sub-slab soil gas sample over a 24 hour period, especially when indoor air samples are being done concurrently. However, samples times up to 24 hours are acceptable (excluding instantaneous or grab samples).

The certified laboratory provides 6-Liter stainless steel canisters with pre-set regulators (based on the sample time prescribed by the investigator). Therefore, the sample time must be established in advance of the sampling event. Investigators can determine a draw rate prior to the sub-slab soil gas sampling event through the installation of a test probe and subsequent draw rate determination with a purge pump.

6.4.2.5 *Calculating Purge Volumes*

Prior to attaching the sample container, the vapor probe should be purged by drawing 3.0 volumes through the probe and connecting tubing. The volume is calculated as follows:

$$PurgeVolume = 3.0\pi r^2 h$$

where r is the inner radius of the probe and connecting tubing, and h is the length of the probe and connecting tubing. The investigator should use a low purge rate with a maximum of 200-ml per minute.

6.4.2.6 *Sample Location*

Vapor probes should be installed in a central location on the slab. Positions near the perimeter of the slab are subject to dilution and should be avoided. The selected location(s) should be chosen in consultation with the property owner. To minimize potential damage to flooring, it may be necessary to select a location in a closet or utility room (where carpeting or tiles are less visible or not present at all).

6.4.2.7 *Number of Sample Points*

The number of sub-slab samples collected is directly related to the goal of the investigation. For a typical single family residential dwelling (approximately 1500 ft²), one vapor probe installed near the center of the slab should adequately document the chemical composition of the sub-slab soil gas. Significantly larger dwellings (or other unique conditions in the subfloor or construction of the foundation) will require additional vapor probes.

Multi-family residential units and commercial or retail buildings will require a more careful review of the building features. Consideration should be given when the building has more than one tenant. Subsurface structures may be present that would facilitate VI and thus degrade indoor

air quality in one portion of the building and not another. Any sampling approach should take into account the different exposure scenarios (e.g., day care, medical facilities) that exist within the building and any sensitive populations that may be exposed to the contaminated vapors.

Multiple vapor probes are necessary for multi-family residential units and commercial or retail buildings. The number and placement of those test points should be determined on a site-specific basis with deliberation given to occupied spaces, segmented areas within larger areas, and potential future use.

Any decision on the number of sub-slab sample points should start with an evaluation of the CSM. If there are indications from the ground water characterization that there could be large lateral changes in concentrations over short distances near a structure, there may be a case for multiple sample points or targeting the worst case areas.

6.4.2.8 *Sample Frequency*

If sub-slab soil gas samples are being collected as a stand-alone determination of the VI pathway, a second confirmation sample may be necessary. Supplemental environmental data (e.g., ground water, indoor air, or near slab soil gas data) may eliminate the need for a second round of sub-slab soil gas sampling. In addition, the Department may accept a single round of sampling in those cases where the analytical results are an order of magnitude below the appropriate screening level.

In situations where sub-slab soil gas sampling is being done to evaluate contaminant patterns or assess background contamination, a decision on the frequency of sampling should be determined on a site-specific basis.

6.4.3 Data Evaluation

Sub-slab soil gas results are generally utilized for comparison to other data sets (e.g., ground water, indoor air, and ambient air). For the most part, these data allow the investigator to determine patterns in the results and differentiate site related compounds from other potential

sources. Results from a sub-slab soil gas investigation should be compared to the NJDEP SGSL. These values were generated from the NJDEP IASL by utilizing an attenuation factor of 0.02. While this factor can be used for a generic screening, a more site-specific evaluation may be appropriate, especially for petroleum hydrocarbon compounds.

For crawl space air samples, the Department has determined that an attenuation factor of 1.0 is applicable, consistent with the USEPA (2002b). Therefore, crawl space indoor air samples can be compared directly to the IASL.

6.5 Conducting A Building Walkthrough and Survey

Preparation is an important aspect for any VI investigation. However, when indoor air samples are going to be collected as part of the investigation, preparation takes on a new level of importance.

A building walkthrough is a critical element of any VI investigation workplan that includes indoor air and/or sub-slab soil gas sampling as an investigative tool. There are several components of a building walkthrough that should be addressed:

- Detection of potential background sources of volatile organic compounds.
- Determination of the building construction
- Recognition of points of VI in a structure
- Identification of possible sample locations
- Education of the occupants on VI and sampling procedures

Ideally, the building walkthrough should be conducted at least one week before the actual indoor air or sub-slab soil gas sampling event. This advance timeframe allows the investigator to identify and eliminate (to the extent practical) potential background sources of indoor air contamination. It also permits the investigator to confirm the sample locations with the occupants and NJDEP ahead of the scheduled sampling episode.

6.5.1 Detection of Potential Background Sources

As discussed in Chapter 8, investigating the VI pathway is greatly complicated by the impact of background contaminant sources. Differentiating the common household sources of poor indoor air quality from those associated with contaminated ground water or subsurface soil is a legal and fiscal dilemma facing both regulatory agencies and potential responsible parties throughout the country.

One of the tools that the Department utilizes in identifying background sources in the indoor air environment is the *Indoor Air Building Survey and Sampling Form* (Appendix B). The survey form allows the investigator to document various information on the building, the occupants, and potential sources of indoor air contamination. The questionnaire was originally developed by NJDEP in 1997 and has since been revised for this guidance document using several similar survey forms prepared by New Hampshire Department of Environmental Services, New York State Department of Health, Vermont Department of Health, and Massachusetts Department of Environmental Protection.

The *Indoor Air Building Survey and Sampling Form* is broken down into eight sections:

- Part I - Basic information on the Occupants of the building, including address, contact's name and phone number, owner's name (if different), and a breakdown of the occupant's ages.
- Part II - The Building Characteristics of the structure under investigation, including building and foundation type, number of floors, heating and ventilation systems, fuel utilized in the building, and the presence/absence of septic systems, sumps, irrigation/private wells, or existing subsurface depressurization systems.
- Part III - Identification of any Outside Contaminant Sources that may exist near the structure being investigated.
- Part IV - Identification of all potential Indoor Contaminant Sources found in the building, the location of the source, and whether the item was removed from the building prior to the indoor air or sub-slab soil gas sampling event. This section also documents remodeling activities, including painting, new carpeting or flooring, and

new furniture. It may be necessary to include additional sheets to inventory all the household products stored within the structure.

- Part V - Survey of Miscellaneous Items related to household activities that may impact indoor air quality, including smoking, dry cleaning clothes, and applying pesticides on the property.
- Part VI - Documentation of Sampling Information, including sample numbers and locations, start time and end times for the sampling event, and the name of the sample technician. This section will be completed on the date of the sampling event.
- Part VII - Existing Weather Conditions during the sampling event should be documented on the survey form. As noted in Chapter 2, weather conditions (especially temperature, barometric pressure, and precipitation) can affect the sample collection and interpretation of the data.
- Part VIII - This section allows the technician to document any General Observations noted during the sampling event that do not fit into the categories noted above.

Another essential tool for pinpointing background sources of indoor air contaminants is the use of handheld field screening instruments. Field portable instrumentation provides useful information for critical decisions in the field. Almost all projects require screening or semi-quantitative data collection during the field-screening phase of the site investigation. These instruments are hand held, rugged, and offer rapid results in the field (NJDEP 2005).

For the purpose of a VI investigation, one of the most important factors in selecting the appropriate field screening instrument is its method detection limits (MDLs). Preferably, the MDLs should be below the action level or levels of concern (NJDEP IASL) for the indoor air.

Recent advances have been made in the development of field portable instrumentation. Photo-ionization detectors (PID) are now providing parts per billion (ppb) detection, making them appropriate for building walkthroughs and surveys during VI investigations. With a ppb detecting PID, individual cans of solvents can be identified as vapor sources and removed from the building in advance of the sampling event.

When household or background sources of indoor air contamination are identified and removed from a building, it may be necessary to ventilate the rooms affected in advance of the air sampling event. This ventilation should be completed at least 24 hours before the commencement of the indoor air sampling event.

6.5.2 Recognition of Points of Vapor Intrusion in a Structure

The entry of organic vapors into a structure is due to the infiltration of contaminants through the floor and walls that are in contact with the soil. Usually, vapors enter a building through poorly sealed utility lines that penetrate the foundation. Other contaminant pathways are through cracks in the walls and floors, sumps, around the wall/floor juncture of floating floor construction or other breaches in the walls or slab.

The *Indoor Air Building Survey and Sampling Form* asks a series of questions that are designed to assist in the identification of potential points of VI. Part II inquires about the type of building foundation, construction of the basement floor, and the presence of sumps. Any obvious breaches in the walls or slab in the basement (or lowest floor) should be noted in Part VIII (General Observations) of the *Indoor Air Building Survey and Sampling Form*. The investigator should also examine the point at which all utility lines enter the structure.

6.5.3 Identification of Possible Sample Locations

The building walkthrough is a perfect time for the investigator to identify possible sample locations that fit the defined investigative goals of the VI investigation workplan.

Sub-slab soil gas samples should be collected from a central location on the slab. Positions near the perimeter of the slab are subject to dilution and should be avoided. To minimize potential damage to flooring, it may be necessary to select a location in a closet or utility room (where carpeting or tiles are less visible or not present at all). The selected location(s) should be chosen in consultation with the property owner during the building walkthrough.

Indoor air samples are generally collected from more than one floor within a structure to address varying risk exposures and as part of the process to distinguish contaminants related to VI from background sources. Thus, the location and position of the sample container will vary depending on which floor the sampling event takes place.

Ground floor (living space) samples should be located to approximate human risk exposure. Thus, these indoor air samples are generally placed at breathing zone height (3-5'). Consideration should also be given on a case specific basis to those situations (such as a day care facility) where a different sampling height may also be appropriate to evaluate a unique setting or population. The basement sample(s) are primarily designed to investigate “worst case” situations within a structure. Therefore, basement samples are positioned as close as possible to the source area (e.g., sumps, major cracks in foundation).

Hence, the building walkthrough allows the investigator to identify potential sample locations for both sub-slab soil gas and indoor air samples. It is recommended that the final locations be selected in consultation with the department’s technical staff.

6.5.4 Education of the Occupants on Vapor Intrusion and Sampling Procedures

One of the responsibilities of the investigator when collecting samples within a structure is to educate the occupants on the VI pathway. Unlike other environmental matrices (soil, ground water, surface water, or sediments), indoor air quality can have an immediate and possible long term affect on human health that is not easily addressed by simple avoidance of the contaminated material.

During the building walkthrough, occupants are likely to raise a number of issues that the investigator should be prepared to answer. Refer to Chapter 11 for a discussion on how to conduct community outreach during the investigation of the VI pathway. In addition, two fact sheets, *Evaluating Indoor Air near VOC Contaminated Sites* (Appendix D) and *Subsurface Depressurization Systems* (Appendix E) may provide further assistance.

The Department has prepared a one page advisory paper entitled *Instructions for Occupants - Indoor Air Sampling Events* (Appendix C). The instructions provide the occupants with a list of actions that should be avoided before and during the sampling event. *The Instructions for Occupants - Indoor Air Sampling Events* sheet should be made available to the occupants at least one week in advance. The paper can be presented during the building walkthrough (assuming the timeframe is met). Any deviation from the instructions noted during the sampling event should be documented on the *Indoor Air Building Survey and Sampling Form*.

6.6 Indoor Air Sampling Procedures

When compared to the other investigative tools available, indoor air sampling (Stage 4C) represents the most direct measure of human health exposure for the VI pathway.

Utilization of the J&E model to extrapolate potential vapor concentrations within a structure based on ground water data can be adversely influenced by numerous geophysical parameters. Data from sub-slab or near slab soil gas sampling employs an attenuation factor that can **estimate** indoor air concentrations resulting from VI. These procedures do not provide actual analytical data on the indoor air quality. Yet, indoor air sampling is not without its problems.

Indoor air quality is affected by a multitude of sources that originate both inside and outside any building. Background contamination should be properly assessed whenever indoor air samples are collected. A detailed discussion on background contamination can be found in Chapter 8. In addition, a variety of meteorological, temporal, and structural factors can influence indoor air concentrations resulting from VI (as discussed in Chapter 2).

Despite these shortcomings, the Department recommends the collection of indoor air samples whenever the potential for VI exists and other investigative tools can not eliminate the pathway. In addition, indoor air samples are appropriate for remedial confirmation purposes.

6.6.1 Application

Analytical results from indoor air sampling events are applicable to the assessment of the VI pathway in several ways.

6.6.1.1 *Stand-Alone assessment of the vapor intrusion pathway*

Analytical results from indoor air sampling may be utilized to determine whether the VI pathway is currently complete for a particular building.

In order for the indoor air results to be acceptable to the Department in any stand-alone assessment of the VI pathway, all sampling procedures provided in this guidance should be followed for the collection of indoor air samples.

The Department does not accept averaging of the results of the indoor air samples within a building. Therefore, each data point should be evaluated independently of each other. Always refer back to the CSM when evaluating data and making any conclusions on the VI pathway.

6.6.1.2 *Evaluating contaminant patterns*

Analytical data from indoor air samples collected from different floors within a structure should be assessed to identify any patterns in particular chemicals, groups of chemicals, and/or their concentrations (both individually and collectively). When combined with data from other matrices (e.g., ground water, soil gas, and ambient air), these patterns may assist in distinguishing likely sources of indoor air contaminants and their pathways. This is important when background sources located within the structure generate the same volatile organic compounds identified as contaminants of concern associated with the site investigation. (For a further discussion on this topic, see Chapter 8.)

6.6.1.3 *Assessing background contamination*

Indoor air samples should be collected concurrently with ambient air and sub-slab soil gas samples. The analytical results are useful in the differentiation of background contamination in indoor air. By comparing the site-specific contaminants of concern detected in the soil gas sample with the indoor air and ambient air results, the investigator can validate the designation of background contaminants and thus limit any remedial action.

6.6.2 Sampling Procedures and Analytical Methods

Analysis of indoor air samples must utilize a laboratory holding a current certification/accreditation from NJDEP Office of Quality Assurance (OQA). At present, there are only two analytical methods where certification is offered - USEPA Method TO-15 and TO-17. Both of these methods analyze for volatile organic compounds. The Department is investigating other analytical methods for possible certification that will expand the list of parameters beyond the standard volatile organics, including naphthalene, formaldehyde, and semivolatile organic compounds.

The first analytical method - TO-15 - employs stainless steel canisters to collect whole air samples. Volatile organic compounds (both polar and non-polar) are concentrated on a solid multisorbent trap, refocused on a second trap, separated on a gas chromatograph column, and passed to a mass spectrometer for identification and quantitation. TO-15 is the principal method used for indoor air samples primarily due to the ease of use for the investigator and the limited obstruction for the occupants of the building (compared to other sampling equipment).

TO-17 uses sorbent tubes for the collection of air samples in the field. There is a large selection of sorbents that can be matched to the contaminants of concern. The tubes are thermally desorbed into a gas

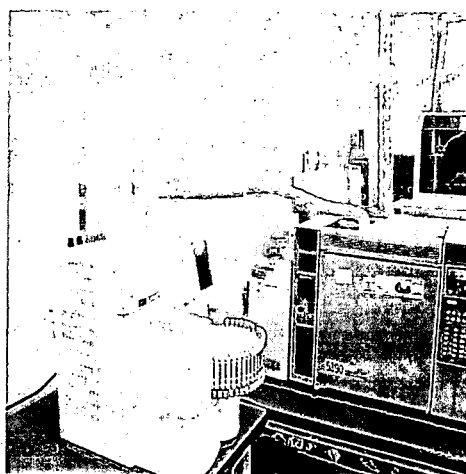


Figure 6-4
Autosampler GC/MS for TO-17 analysis
(courtesy of Severn Trent Laboratories)

chromatogram/mass spectrometer instrument system. The method requires specific collection procedures and states that after desorption on to the column the samples are to be analyzed in accordance with USEPA Method TO-15.

Additional information on these two analytical methods can be found in Appendix I, Quality Assurance Requirements. Alternative methodologies for the collection and analysis of indoor air samples should be submitted and approved by the Department in advance of the field activities.

Regardless of the analytical method, it is recommended that the investigator complete the NJDEP *Indoor Air Building Survey and Sampling Form* (Appendix B). The survey form should be completed as part of the building walkthrough (conducted prior to the sampling event) and include information obtained during the actual sampling episode. Similar to the sub-slab sampling procedures, the general condition of the structure should be documented, including the presence of sumps, cleanouts and floor drains. Refer to Section 6.5 for additional information on the building walkthrough and the survey form.

In light of recent events related to homeland security, it is highly recommended that suitable precautions be taken whenever VI investigations include outside air sampling. The sampling equipment (e.g., stainless steel canisters) and related devices are not familiar to most individuals and may be misinterpreted as a safety concern. Therefore, notification about the sampling event should be provided to the local police and fire departments, in addition to the municipal officials. It may be necessary to demonstrate the operations of the sampling equipment to these officials. A label should be affixed to the sampling device explaining the nature of the equipment and all appropriate contact information in case there are further questions. The individuals collecting the indoor air samples should be prepared to provide proper identification to the building occupants.

6.6.2.1 TO-15 Requirements

- The sampling event should be conducted by collecting a minimum of one indoor air sample from the ground floor (living space) at each property using 6-Liter stainless SUMMA canisters (or other specially prepared stainless steel canisters) and analyzed for VOC using USEPA Method TO-15. If a basement or crawlspace exists, a second canister air sample

should be collected as part of the minimum requirements. Breathing zone height (3-5') will be appropriate for the ground floor sample collection, whereas the basement sample should be positioned as close as possible to the source area (e.g., sumps, major cracks in foundation). Additional canister air samples may be necessary for larger buildings to properly assess indoor air quality. The rationale for the final number of air samples collected per building should be provided in the VI investigation workplan.



Figure 6-5
Stainless steel canister

- In general, one ambient (outdoor) sample should be taken per sampling event concurrently with indoor samples to assist in evaluating background contaminant levels. This ambient air sample should be taken at breathing zone height and located in a reasonably representative area (e.g., not immediately next to auto traffic or other potential sources). See Section 6.1.3.3 for additional guidance on the appropriate number of ambient air samples.
- Air samples should be collected over a 24-hour period (a minimum 8 hour sample may be substituted with proper justification, if necessary).
- Air Filters are recommended for each canister to prevent clogging of the orifice during sample collection.
- All results are to be reported in ppbv. The laboratory should also report the data in $\mu\text{g}/\text{m}^3$ in a separate column from the ppbv results.
- For USEPA Method TO-15, 6-Liter stainless steel canisters should be used for the indoor air sample collection. Alternative sizes or types of sample containers are not acceptable for indoor air samples.

6.6.2.2 TO-17 Requirements

- The sampling event should be conducted by collecting a minimum of one indoor air sample from the ground floor (living space) at each property and analyzed for VOC using USEPA Method TO-17. If a basement or crawlspace exists, a second sample should be collected as part of the minimum requirements. Breathing zone height (3-5') will be appropriate for the

ground floor sample collection, whereas the basement sample should be positioned as close as possible to the source area (e.g., sumps, major cracks in foundation). Additional air samples may be necessary for larger buildings to properly assess indoor air quality. The rationale for the final number of air samples collected per building should be provided in the VI investigation workplan.

- For each sampling point, the investigator will be required to collect two sorbent tubes for each sampling point in parallel. The sorbent material in each tube must be the same material.
- In general, one ambient (outdoor) sample should be taken per sampling event concurrently with indoor samples to assist in evaluating background contaminant levels. This ambient air sample should be taken at breathing zone height and located in a reasonably representative area (e.g., not immediately next to auto traffic or other potential sources). See Section 6.1.3.3 for additional guidance on the appropriate number of ambient air samples.
- The pump rate must be set so that the final calculated reporting limit used by the laboratory shall be less than or equal to 0.5 ppb.
- The minimum sample collection time for the sorbent tubes has been established by NJDEP as eight (8) hours. A twenty-four (24) hour sample collection time is the preferred sampling time, since it provides a longer time weighted average for exposure.
- The choice of sampling apparatus and sorbent material is left to the investigator. However, the apparatus must conform to Section 6.3.1 of Method TO-17, which requires accommodations for two sampling tubes with the capability of independent control for sampling rate at a settable value in the range of 10 to 200 ml/min.
- All quality assurance provisions stipulated in Appendix I (Quality Assurance Requirements) shall be followed for USEPA Method TO-17.
- All results are to be reported in ppbv. The laboratory shall also report the data in $\mu\text{g}/\text{m}^3$ in a separate column from the ppbv results.

6.6.2.3 *Number of Sample Locations*

As previously stated above, a typical single family residential dwelling (approximately 1,500 ft²) should have one indoor air sample collected from the first floor and one from the basement or crawl space (if present). Significantly larger dwellings may require additional samples.

Multi-family residential units and commercial or retail buildings will require a more careful review of the building features. Consideration should be given when the building has more than one tenant. Subsurface structures may be present that would facilitate VI and thus degrade indoor air quality in one portion of the building and not another. Any sampling approach should take into account the different exposure scenarios (e.g., day care, medical facilities) that exist within the building and any sensitive populations that may be exposed to the contaminated vapors. Multiple indoor air sample locations are necessary for multi-family residential units and commercial or retail buildings.

6.6.2.4 *Sample Frequency*

As discussed in Chapter 2, seasonal variability in vapor concentrations necessitates (in most circumstances) collecting more than one round of indoor air samples.

If indoor air samples are being collected as a stand-alone determination of the VI pathway, a second confirmation sample may be necessary. One of the two sampling events should take place during the months between November and March, since these are generally "worst case" conditions for VI. However, the Department will accept a single round of sampling (irrespective of the seasonal timing of the sample event) in those cases where the results are an order of magnitude below the appropriate screening level.

6.6.2.5 *Pressure and Temperature Issues*

The laboratory prepares the canisters and establishes the flow rate of the regulators based on the barometric (atmospheric) pressure and temperature inside of the laboratory. The canister pressure must be set at approximately -30 inches of mercury at the laboratory prior to shipment. Once in the field, temperature and atmospheric pressure changes that occur over the sample collection time will affect the rate of sample collection. A sharp decrease in the temperature (from the temperature at which the regulators are set in the laboratory) during the period of sample

collection will increase the flow rate into the canister, while an increase in temperature will slow the flow rate.

Thus, the Department recommends the collection of ambient temperature and pressure readings during the collection of all air samples.

For an exterior ambient sample, there are two ways to obtain this information. Atmospheric pressure and temperature can be acquired from the nearest weather reporting station. Two websites that may be useful to the investigator are the National Oceanic and Atmospheric Administration, National Weather Service website at <http://www.weather.gov> or Weather Underground at <http://www.wunderground.com/>. Alternately, the investigator can bring portable meteorological instrumentation on site to obtain the information real time.

Temperature for interior samples should be obtained using portable meteorological instrumentation with readings taken inside the structure. For all indoor air samples, individual temperature readings will be necessary for each sample location. Larger commercial buildings may also require barometric pressure readings for each sample.

6.6.3 Data Evaluation

Indoor air results are compared to the NJDEP IASL. Ideally, the data will establish patterns in the contaminant distribution, both within the structure (basement verses first and second floors, etc.) and outside the structure (ambient verses indoor air concentrations). In addition, comparisons should also be made between the indoor air results and other data sets (e.g., ground water, indoor air, and ambient air). For the most part, these data allow the investigator to determine patterns in the results and differentiate site-related compounds from other potential sources.

The results of air samples collected within a building's crawl space should be compared to the NJDEP IASL.

7.0 EVALUATION OF ANALYTICAL RESULTS

Once the data packages have been validated, the investigator should evaluate the analytical results by comparing the soil gas, ground water, and indoor air results to the appropriate screening levels.

7.1 Background Sources

One of the most critical steps during a VI investigation is the evaluation of analytical data - particularly as it relates to source identification. Unlike other pathways, the potential for background contamination is significant. The investigator should follow the framework for distinguishing background sources found in Chapter 8.

NJDEP relies on a *multiple lines of evidence* approach when assessing potential background sources of indoor air contamination, employing a series of primary and secondary factors. The primary factors are the identification of site-specific contaminants of concern, collection of sub-slab soil gas and ambient air data, and the evaluation of the results. The secondary factors include completion of the *Indoor Air Building Survey and Sampling Form*, review of indoor air background databases, and collection of exterior soil gas data. As a general point, remedial action will not be required when the site-specific ambient air results are in excess of the indoor air results. In these cases, the Department should assess the validity of the ambient air results.

An assessment of potential background sources should be included in any data evaluation process.

7.2 Ground Water Samples

Assuming the samples are collected consistent with the procedures and recommendations in Section 6.2, the data should be compared to the applicable NJDEP GWSL. The exceedance of these screening levels for any volatile will necessitate further investigation. However, it should not be assumed that elevated ground water concentrations automatically indicate that unacceptable levels of vapors are currently entering the structure. If exceedances of GWSL are

minor and sporadic, appropriate statistical analytical methods may be considered for data evaluation.

The ground water data shall be evaluated to determine whether the contaminant plume has been delineated to the extent needed to assess the VI pathway. If it is determined that the plume has not been sufficiently delineated, additional ground water samples will be required to complete the delineation as it pertains to this pathway. All existing buildings that are located within 100 feet horizontally of the shallow plume's perimeter should be identified. The Department does utilize a 30-foot distance criterion (both horizontal and vertical) for petroleum related contamination (see Chapter 9 for further discussions). Depending on the soil type, the presence of preferential pathways, and/or certain hydrogeologic features, the two distance criteria may have to be modified. The results of this effort will highlight those structures that will necessitate further investigation for the VI pathway.

7.3 Vertical Ground Water Contaminant Profile

At sites where a clean water lens is investigated, vertical profiles of volatile levels in ground water may reveal various patterns that are likely to have different implications for the current and future risk of vapor intrusion. The following guidelines can be used to interpret the data.

A **six foot thick lens** of ground water with contaminants below the GWSL can be considered sufficient justification to conclude the plume is not a source for vapor intrusion in the immediate vicinity. Additional ground water sampling for a VI investigation should not be required where such a lens exists unless conditions change, or are expected to change to include any circumstances that will cause the water table elevation to decrease significantly. However, ongoing monitoring as part of an approved remedial action may be required.

If a **lens between three and six feet thick**, not exceeding the GWSL, exists between the vadose zone and the part of the plume that does exceed GWSL, significant off-gassing into the vadose zone is unlikely. However, in this situation ongoing, periodic water level and/or ground water monitoring should be performed to confirm the continuing presence of a "below GWSL lens" of

at least 3 feet in thickness. If water level data or other information strongly suggest that a below GWSL lens at least 3 feet thick is not present throughout the year, additional investigation of the VI pathway (soil gas and/or indoor air sampling) is recommended. If possible, the additional investigation should be done during, or immediately after, a time period when a below GWSL lens was not present.

A below GWSL **lens less than 3 feet thick** overlying a plume which exceeds the GWSL should trigger additional investigation of the VI pathway and possibly ongoing ground water monitoring. Conditions which should be considered in designing the next investigative step include: types of contaminants present; concentrations of contaminants in the various depth intervals sampled; and thickness of the below GWSL lens in the vertical profile nearest to the structure.

7.4 Sub-Slab Soil Gas Samples

The compounds detected in the sub-slab (or near slab, when approved) soil gas results should be compared with the site-specific contaminants of concern (including degradation products) identified from the contaminated ground water or soil. The compounds should be similar. If additional compounds are seen in the soil gas results, a secondary VI source may be present. A supplemental investigation of the local soils may be warranted.

The analytical results of the sub-slab soil gas samples should be compared to the NJDEP SGSL. The NJDEP SGSL were prepared using the NJDEP IASL with an attenuation factor of 0.02. The investigator may propose an alternative attenuation factor consistent with the procedures for a Site-Specific Screening Process (Stage 6).

If the soil gas results exceed the applicable NJDEP SGSL, additional investigation of the VI pathway is necessary. Unless the investigator is proposing a site-specific approach that is acceptable to the Department, indoor air sampling will be necessary.

In those situations where the soil gas results do not exceed the NJDEP SGSL but ground water quality exceeds the generic GWSL, a site-specific determination can potentially be made that no additional VI investigation is needed. This determination should be based on an accurate CSM and representative ground water data which indicates:

- that shallow ground water concentrations are unlikely to increase in the future; and,
- other site conditions at the time of sampling (e.g., soil moisture, % oxygen in vadose zone) are unlikely to change enough to result in higher soil gas volatile levels.

Consideration should be given to whether volatile levels in ground water greatly or only slightly exceed the GWSL. Also consider whether the ground water plume is still growing, at steady-state conditions, or in the process of attenuating. In the situation where the ground water plume is still growing, additional investigation is apt to be necessary. If known, the vertical distribution of contaminant concentrations in ground water may also be relevant to this decision.

Based on the sampling plan, multiple sub-slab soil gas samples may have to be collected. In general, the Department does not allow the results of the sub-slab soil gas samples to be averaged across the subsurface of a building. Therefore, each data point should be evaluated independently of each other.

7.5 Indoor Air Samples from the Basement

The analytical results of the indoor air samples should be compared to the NJDEP IASL. The investigator may propose alternative screening levels consistent with the procedures for a Site-Specific Screening Process.

If the indoor air results exceed the applicable NJDEP IASL, additional investigation of the VI pathway is necessary to confirm the results. Once confirmed, the investigator should propose an appropriate remedial action, as discussed in Chapter 10.

Multiple samples collected from different locations on the same floor may identify probable background sources when combined with a building walkthrough and survey. Compare the

locations of suspect consumer products (e.g., paints, thinners) or household activities (e.g., hobbies, smoking) with the indoor air sample results. Evaluate whether particular volatile organic compounds are higher or lower in certain portions of a building and if they correlate with identified background sources. Additionally, determine if the site-specific contaminants of concern compare to the indoor air compounds detected in the sample results. The need to collect multiple indoor air samples from the same level is a site-specific determination based on the likelihood of significant background sources within a structure.

In addition, compare the analytical results with potential VI routes through the building slab or foundation (e.g., sumps, utility lines, major cracks). Depending on the ventilation system in the basement, differences in concentrations of site-specific contaminants of concern between multiple sample points may be related to their relative position near VI points (and not background sources).

7.6 Multiple Indoor Air Samples from Different Floors

Ideally, indoor air samples should be collected from at least two separate floors within a structure, preferably the basement (or lowest floor) and the level immediately above it. In part, the rationale for this approach is to provide the investigator with analytical results that may assist in the assessment of potential background contaminant sources. This is critical in situations where sub-slab soil gas samples are NOT collected.

Compare the results for individual compounds on each floor. In general, the concentrations should decrease as you move away from the source. Thus, if VI from contaminated ground water or subsurface soil is the main source, the highest concentrations should be in the basement (or lowest floor) and decrease as you move up to the first or second floor. Conversely, if the higher concentrations are found in the upper floors (when compared to the basement results), a background source unrelated to the site is probably located within the building on the floor with the highest concentrations. Deviations from this general understanding of vapor movement may exist in situations where a vertical pathway allows vapors to move quickly from one floor to the next (e.g., elevator shafts, laundry chutes).

The first step in differentiating background contamination during indoor air sampling events is to identify the site-specific contaminants of concern (based on ground water or subsurface soil data). When these contaminants of concern are found in potential background sources located within the building under investigation, results from multiple indoor air samples can be compared to the relative concentrations of related contaminants.

For example, benzene, ethylbenzene, toluene and xylenes (BTEX) are common contaminants associated with gasoline. Compare the concentrations of each of these contaminants relative to each other. Evaluate whether a similar relationship exists between the contaminants detected in other samples collected either on the same or different floors of the building. If benzene and toluene generally have a 1:1 ratio in the basement and the 2nd floor samples have 3x as much toluene as benzene, it is probable that a secondary background source of toluene is located on the 2nd floor (e.g., nail polish).

7.7 Indoor Air and Sub-Slab Soil Gas Samples

The Department recommends that the collection of indoor air and sub-slab soil gas samples be conducted concurrently during the investigation of the VI pathway. The combination of indoor air and sub-slab soil gas results will assist in identifying likely background indoor air sources and verify whether a VI source exists below the building (instead of extrapolating contaminated ground water or subsurface soil results from indoor air).

The Department has developed a Remediation Decision Matrix (part of the Decision Flow Chart - Appendix A) to assist the investigator in assessing the VI pathway. Specifically, the Remediation Decision Matrix evaluates the relationship between the sub-slab soil gas and indoor air sample results, providing guidance on the appropriate action (e.g., no action, monitoring, further investigation, and mitigation).

Frequently, contaminants will be found in the indoor air, but not the sub-slab soil gas samples. The compounds are likely originating from background sources unrelated to VI (especially if

they are not site-specific contaminants of concern). In these cases, the Remediation Decision Matrix directs the investigator to evaluate vadose zone (soil) contamination and preferential pathways as potential contributors to indoor air contamination that might not be detected in the subsurface soil gas results. Once it is established that VI is not contributing to the indoor air contamination, no further action is necessary for this pathway.

The investigator will identify cases where the indoor air concentrations are below the IASL, but the sub-slab soil gas results are elevated, indicating a potential source in the subsurface. In these situations, the Remediation Decision Matrix differentiates between elevated sub-slab soil gas results that are less than or more than 10 times the SGSL.

For sub-slab soil gas results that are 10 times or less the SGSL, the options are no further action or continued monitoring. The higher the sub-slab soil gas exceedance, the more probable it is that monitoring will be necessary.

If the sub-slab soil gas results are greater than 10 times the SGSL, the option of no further action is not available. In these cases, the investigator should either continue monitoring the sub-slab soil gas concentrations or implement a remedial action. The change in remedial options is due to the increased likelihood that vapor intrusion will occur in the future if the source of the high soil gas concentrations is not addressed.

When more than one option is available in the Remediation Decision Matrix (decision points), the investigator should use professional judgment when determining which action is appropriate. Factors to be considered at these decision points include:

- the relative exceedance of the screening level,
- the ratio of the sub-slab soil gas and indoor air results,
- the current building construction (e.g., 1st floor garages, sub-slab vapor barriers, etc.),
- possible effects of background sources of contamination, and
- sampling errors.

In many situations, both the sub-slab soil gas and the indoor air results will exceed the applicable screening levels. If the sub-slab soil gas data exceeds the SGSL by more than 10 times (with indoor air results exceeding the IASL), the investigator should implement a remedial action to address the VI pathway. The evidence clearly points to VI impacting the indoor air quality of the structure.

Another decision point occurs, however, when the sub-slab soil gas results exceed the SGSL by 10 times or less and the indoor air results are greater than the IASL. In these situations, the investigator should use professional judgment to determine whether the appropriate action is to investigate the VI pathway further or execute a remedial action. An evaluation of the sub-slab soil gas and indoor air results should be conducted to assess the relative exceedance in comparison to the screening level.

The investigator should look at the exceedance multipliers (analytical results divided by the applicable screening level) for both soil gas and indoor air. If the VI pathway is complete, the soil gas multiplier should be similar to or higher than the indoor air multiplier, which necessitates mitigation. In situations where the indoor air multiplier is notably higher than the soil gas multiplier, further investigation is warranted to assess whether an indoor background source is present. This scenario, however, does not eliminate the possibility that the VI pathway may still be impacting to the air quality within the structure and should be addressed.

The clearest picture of the contribution of background indoor air sources, though, is observed when sub-slab soil gas results are combined with indoor air data collected from different floors and/or various locations on each floor.

The summary table below presents soil gas and indoor air results collected during an investigation of a gasoline plume in the coastal plains of New Jersey. Even though free product is found adjacent to the building, numerous gasoline-related compounds are non-detect in the sub-slab soil gas samples - probably due to biodegradation. Other gasoline related compounds, namely cyclohexane, MTBE, and 2,2,4-trimethylpentane, are detected at high concentrations in the sub-slab soil gas with decreasing levels in the basement and first floor. This strongly supports

the assumption that the VI pathway is complete. In fact, the sub-slab soil gas multiplier is greater than 10 times the applicable SGSL and the IASL are exceeded. Thus, mitigation is necessary (consistent with the Remediation Decision Matrix) to address the VI pathway.

There are, however, contaminants that are present in the basement or first floor indoor air samples and not in the sub-slab soil gas. Had MTBE not been present, the Remediation Decision Matrix would recommend no further action. A review of the building survey form in this particular case reveals that the occupants utilize various solvents as part of their operations, including methylene chloride, toluene, and xylenes. These indoor air contaminants originate from background sources and should not be factored into any NJDEP approved remedial actions related to site contaminants. For an example of how multiple lines of evidence are applied in the determination of vapor intrusion, consult Sanders & Hers (2005).

Table 7-1
Illustrative Example of Sub-Slab Soil Gas and Indoor Air Results

| Chemical | Soil Gas Results Sub-slab | IA Results Basement | IA Results 1st Floor |
|------------------------------|------------------------------|------------------------|-------------------------|
| Benzene | ND | ND | ND |
| Cyclohexane | 15,000 | 120 | 25 |
| Ethylbenzene | ND | ND | 10 |
| 4-Ethyltoluene | ND | ND | 19 |
| Methylene chloride | ND | ND | 100 |
| MTBE | 18,000 | 140 | 50 |
| Toluene | ND | ND | 45 |
| 1,2,4-Trimethylbenzene | ND | ND | 17 |
| 1,3,5-Trimethylbenzene | ND | ND | 5.9 |
| 2,2,4-Trimethylpentane | 93,000 | 700 | 160 |
| Xylenes (<i>m & p</i>) | ND | 14 | 39 |
| Xylenes (<i>o</i>) | ND | ND | 17 |

Results in $\mu\text{g}/\text{m}^3$

ND = non-detect

7.8 Indoor Air Data Evaluation

As discussed in Section 4.3, indoor air analytical results are compared to the Table 1 IASL. If VI related indoor air concentrations exceed the IASL, additional actions are indicated to address the VI pathway. These actions may include further investigation/evaluation of the potential source of the VI and/or the development of a plan of action to mitigate potential impacts to the indoor air quality of the building.

Confirmatory sampling should be conducted to verify the presence of elevated contaminant levels in a building and to substantiate the occurrence of VI (distinct from background contaminant sources). Confirmatory sampling should include indoor air, sub-slab or near slab soil gas, and ambient air samples.

In addition, indoor air analytical results are compared to the RAL found in Table 2. Initial sample results exceeding the RAL will require that confirmatory samples be collected **immediately** upon receipt of the data. Implementation of an interim remedial measure (IRM), such as the installation of a subsurface depressurization system, is necessary when VI related indoor air concentrations exceeding the RAL are confirmed. The **rapid** implementation of the IRM is essential to address the potential for adverse impacts to public health.

Health Department Notification Levels (HDNL), developed in consultation with the NJDHSS, are also listed in Table 2. These values, when exceeded in occupied buildings, represent levels that trigger the Department's referral of a site to the local health department or NJDHSS. The local health department or NJDHSS would then have the information necessary to make a decision in consultation with the NJDEP regarding the need for any emergency actions, such as the evacuation of an occupied building. On a case by case basis, the health departments may also be notified when elevated indoor air levels below the HDNL are present in an occupied school, day care center, health care facility, or other structure with sensitive receptors.

Should the driver chemical at a site be one of the contaminants that does not currently have an RAL or HDNL value, the Department's Environmental Toxicology and Risk Assessment (ETRA) unit may be contacted at 609-633-1348 to identify an applicable level.

7.9 Official Notification

Although investigators may elect to forward results (or be bound to do so by property access agreements), it is NJDEP's policy to officially notify property owners about their indoor air and/or soil gas analytical results whenever a oversight document is in place. The Department will also notify current tenants about the analytical results. However, it is ultimately the property owner's responsibility to ensure that all potentially impacted current and future building occupants are informed.

The written reports from NJDEP will consist of a cover letter explaining the findings and a table summarizing the analytical results. The letter should include language informing the property owner of the Property Condition Disclosure requirements as per N.J.A.C. 13:45A-29.1.

In cases where the compounds are concluded to be originating from background sources unrelated to VI, the occupants will be directed to consult with the local health department on ways to reduce background contamination. Refer to Chapter 11 for guidance on community outreach and the communication of investigative results to building occupants/owners.

8.0 BACKGROUND CONTAMINATION

One of the most difficult facets of investigating the VI pathway is assessing the impact of background contaminant sources. Indoor air quality is affected by a multitude of sources that originate both inside and outside any building.

VI from a discharged hazardous substance, hazardous waste, or pollutant to ground water or soil is a regulatory concern of the Department. However, other contaminant sources (e.g., ambient outdoor air, consumer products, building materials) that may impact indoor air quality are the responsibility of different programs within NJDEP, the New Jersey Department of Health and Senior Services (NJDHSS), and/or the federal government.

According to the USEPA, background refers to constituents that are not influenced by the releases from a site, and is usually described as naturally occurring or anthropogenic (USEPA 2002a). For the intentions of this guidance document, background will refer to any contaminants not directly resulting from subsurface VI related to a discharge. In many cases, individual contaminants found in indoor air may result from both subsurface VI and background sources.

Despite the varying sources impacting indoor air quality and the numerous regulatory groups overseeing them, it is imperative that all the results of any VI investigation be reported to the occupants, irrespective of the ultimate responsibility for the indoor air contaminants.

8.1 Background Investigations

Once the decision has been made to conduct indoor air sampling (consistent with the guidance found in Chapter 6), the investigator should consider the proper exploratory tactic to distinguish site related VI from background contamination.

Individual states, such as Colorado and Massachusetts, have long recognized the risk to human health from VI. Now, this exposure pathway is being assessed at a multitude of RCRA, Superfund, Underground Storage Tank programs and state lead sites nationwide, along with the more traditional dermal and ingestion exposure pathways.

Yet, there are major differences in the method of investigating VI that distinguish it from the other pathways. One of those dissimilarities is the assessment of background contamination.

Background contamination is typically identified through the collection of upgradient or upstream samples for ground water and surface water respectively. With soil investigations, background samples are collected from areas of the site not impacted by current or historic operations and having similar soil characteristics. Building interiors do not generally provide for “upgradient” or “non-impacted” sampling locations in order to establish background indoor air concentrations. Thus, an alternative approach is necessary for indoor air assessments to distinguish background contamination from site related VI.

8.2 Background Indoor Air Sources

Sources of background indoor air contamination can be broken down into several categories – household activities, consumer products, building materials and furnishings, and ambient air pollution. The conveniences of life that people often take for granted greatly impact indoor air quality. With the average American spending over 90 percent of their time inside where contaminant concentrations are often much higher than outside (USEPA 2001c), the numerous sources impacting the air quality of buildings warrants closer scrutiny.

Smoking tobacco products, parking a car in an attached garage, using a kerosene heater, burning scented candles, dry cleaning clothes - all these household activities contribute to potentially unhealthful contaminant concentrations in the indoor air. Over 50 carcinogenic compounds are found in tobacco smoke alone (Cal EPA 1997). In fact, cigarettes account for 45% of the benzene found in indoor air (Ott and Roberts 1998).

Consumer products represent a second source of indoor air contamination that should be evaluated when assessing the contribution from VI. Mothballs (1,4-dichlorobenzene), nail polish remover (acetone), rug spot cleaner (tetrachloroethene), floor polish (xylenes), drain cleaner (1,1,1-trichloroethane), and gasoline (benzene, toluene, ethylbenzene, and xylenes) are just a few

of the examples. (Refer to Appendix H, *Common Household Sources of Background Indoor Air Contamination*, for additional information). With the proprietary nature of consumer products today, it is often impossible to determine what chemicals are contained in most products. Either the labels are silent on the ingredients or they will refer to some generic constituent, such as "petroleum products."

Building materials and furnishings are another source of indoor air contamination, particularly when they are new. Whether it's carpeting, shower curtains, fabrics and draperies, furniture, building insulation, or pressed wood products (particleboard, hardwood plywood, and medium density fiberboard), indoor air quality can be significantly affected by volatile organic compounds and formaldehyde emanating from these products.

Numerous materials found in buildings, such as carpeting, fabrics, and wallpapered gypsum board, can act as "sinks" that retain indoor air pollutants and subsequently release them over a prolonged period of time (Won et al. 2000). This process is called sorptive interaction, based in part on the work at the University of Texas at Austin - the Texas Institute for the Indoor Environment. Carpets represent a significant sink for non-polar volatiles, while virgin gypsum board interacts primarily with highly polar volatiles.

Outdoor air typically enters a structure through infiltration, natural ventilation, and mechanical ventilation. Yet, studies have shown that common organic pollutants are 2 to 5 times higher inside a structure compared to levels in the ambient air (USEPA 1987). Over the last three decades since the passage of the Clean Air Act in 1970, the pollutant concentrations in the outdoors have been greatly reduced. Despite this turnaround, ambient air in urban environments (and other unique circumstances) does require careful consideration when evaluating indoor air results.

8.3 Methods to Address Background Sources

NJDEP relies on a multiple lines of evidence approach when assessing potential background sources of indoor air contamination. This approach employs a series of primary and secondary factors that collectively gauge the often confounding contaminants found in indoor air and determine with reasonable certainty the contribution from VI.

Utilizing this methodology, the primary factors (discussed below) provide more significant evidence when compared to the secondary factors (a “weighted” average). The multiple lines of evidence approach is not designed to be a mathematical calculation, but rather a professional judgment based on a progression of empirical facts, some more relevant than others.

8.3.1 Primary Factors

The primary factors (in no particular order) for assessing background contamination in indoor air are provided below.

8.3.1.1 *Site-Specific Contaminants of Concern*

A well delineated ground water plume (or subsurface soil contamination) with identified chemical contaminants can greatly limit the scope of any investigation. Potential degradation products must be included in the contaminants of concern list. However, indoor air investigations are often conducted with just basic information where ground water or subsurface soil data are seldom extensive or complete. Thus, insufficient data may exist preventing contaminants of concern from being determined prior to the collection of indoor air samples. It should be noted that the Department requires indoor air samples collected during initial rounds to be analyzed for the full list of parameters (based on the methodology) and not a reduced list. Subsequent phases of soil gas sampling can employ a reduced parameter list as part of an approved VI investigation workplan.

8.3.1.2 *Sub-slab soil gas sampling*

Collecting vapor samples from below the structure's slab is an excellent tool for differentiating contaminants originating in ground water and subsurface soils from those associated with background sources. The Department's procedures for collecting sub-slab soil gas samples, as outlined in Chapter 6.4, should be followed in order to utilize the data in the evaluation of background contamination.

Sub-slab soil gas samples, collected concurrently with indoor air samples from the same structure, will allow for a comparison between the data. The investigator should evaluate the contaminants of concern found in the ground water and subsurface soils (and their concentration ratios relative to each other). Do they correlate with the results from the sub-slab soil gas and indoor air samples? Correlation between these different sets of data would indicate that the VI pathway is complete.

Frequently, contaminants will be found in the indoor air, but not the sub-slab samples. In these cases, the compounds are likely originating from background sources unrelated to VI, and the occupants will be directed to consult with the local health department on ways to reduce background contamination.

A concentration gradient between the sub-slab and indoor air samples (greater than 20x higher in the sub-slab) strongly suggests that the VI pathway is complete. Conversely, higher concentrations within the structure (when compared to sub-slab results) would indicate that a secondary background source is likely present inside. This scenario, however, doesn't eliminate the fact that the VI pathway may still be contributing to the poor indoor air quality within the structure.

The investigator must consider the presence of preferential pathways. The VI pathway may be complete even though low sub-slab concentrations are detected. Vapors, particularly from contaminated soils, may migrate along preferential pathways above the depth of the structure's

slab. Thus, contaminated vapors may adversely impact a structure's indoor air quality without the presence of elevated sub-slab vapors.

8.3.1.3 *Ambient (outdoor) air sampling*

NJDEP recommends the collection of a minimum of one ambient air sample during every indoor air sampling episode. The results of the ambient air sample can be utilized to evaluate the influence of outside air on the indoor air quality. This provision is particularly important for urban settings due to the industrial and automotive emissions typical of larger cities. In general, remedial action will not be required when the site-specific ambient air results are in excess of the indoor air results. In these cases, the Department should assess the validity of the ambient air results.

NJDEP Air Toxics Program measures a suite of toxic VOC, semivolatile compounds and metals at four monitoring sites – Camden, Elizabeth, Chester and New Brunswick. These four sites in the Air Toxics Monitoring Network provide information on the spatial variation of air toxic concentrations in the state.

While data from the NJ Air Toxics Monitoring Network can not replace site-specific results, it does provide a general indicator of potential ambient air concentrations in a region of New Jersey.

8.3.2 Secondary Factors

The secondary factors for assessing background contamination in indoor air provided below.

8.3.2.1 *Building survey*

NJDEP utilizes the *Indoor Air Building Survey and Sampling Form* (Appendix B) when collecting sub-slab soil gas and indoor air samples. This questionnaire covers numerous issues,

including building characteristics, indoor contaminant sources, miscellaneous items (such as "do you smoke or dry clean clothes?"), sampling information, and weather conditions.

When the questionnaire is completed in advance of the indoor air sampling event and as part of the building walkthrough, potential background sources can be identified and removed/eliminated prior to sampling.

8.3.2.2 *Indoor air background databases*

Utilization of local, regional, national, or international indoor air background databases is a secondary method for assessing background contamination. The USEPA National Ambient VOC Database Update (USEPA 1988) is one resource for determining typical background concentrations in buildings.

In addition, NJDEP has conducted a literature review to determine available information regarding ambient levels of VOC in homes and other structures (Appendix F). Much of this information was drawn from studies designed to determine personal exposures to these chemicals, but many of them included dedicated indoor air sampling where measurements were taken at an indoor fixed location. Most of these studies were done in urban areas throughout the United States, including many in New Jersey. While several chemicals were commonly observed in indoor air, many other volatiles regulated by New Jersey have never been evaluated. It is likely that many of them would not be found; however, this needs to be confirmed via analytical methods that determine all regulated compounds of interest. Therefore, the Department is conducting research to confirm the presence or absence of all regulated VOC using stainless steel canisters and USEPA method TO-15.

Care should be taken to avoid placing too much emphasis on background literature values. They are just one of many tools that can be used when assessing indoor air contamination.

8.3.2.3 *Exterior soil gas sampling*

Department experience has shown exterior soil gas sampling to be an effective screening tool when selecting monitor well locations for ground water delineation of contaminant plumes. However, its success in VI investigations has been suspect. Concerns over false negative results have limited the use of exterior soil gas sampling in determining the presence/absence of a VI problem affecting indoor air quality.

Exterior soil gas sampling may be appropriate, though, when differentiating VI from background contaminant sources as part of an indoor air sampling event. While the Department recommends utilizing sub-slab soil gas sampling for this purpose, occupants are not always receptive to drilling a hole in their slab. Collecting soil gas samples from the foundation perimeter (near slab) is a reasonable alternative in this circumstance.

8.3.3 Other Issues

Besides the primary and secondary factors, there is additional information that may assist in the evaluation of potential background indoor air sources.

It is important to understand the structure where samples are being collected. HVAC systems that generate positive air pressure can reasonably be expected to prevent or minimize VI within the structure. Conversely, a dirt floor (or poorly vented crawlspace) instead of a concrete slab may significantly increase contaminant concentrations within the structure above levels normally calculated using attenuation factors or the J&E model.

Additionally, it is imperative that data quality be assessed before, during and after the sampling event. Select a laboratory that is competent to analyze the soil gas/indoor air samples and is familiar with the analytical method. In New Jersey, the investigator shall utilize a laboratory from the state's laboratory certification program for USEPA Method TO-15 and TO-17 to ensure quality data. Collect the appropriate quality control samples (blanks, duplicates, etc.). Once the

laboratory submits the results, validate the data packages. Laboratory contaminants can occur during the analysis of indoor air samples, particularly with polar compounds.

In order to collect an indoor air sample that is both representative of indoor conditions and avoids the common sources of background air contamination, the occupants are instructed as to the do's and don'ts of indoor air sampling. These directions are contained in the *Instructions for Occupants - Indoor Air Sampling Events*, found in Appendix C. This precautionary step may eliminate potential background sources and avoid the process of distinguishing contaminant causes in indoor air samples.

Finally, the assessment of VI and indoor air results should take into account the appropriate application of federal and state policies relating to the role of background. USEPA policy recommends that contaminant concentrations attributable to background sources not be eliminated from the risk assessment process (USEPA 2002a). This allows for the total risk to be properly assessed, even though the remedial action ultimately may not address the background sources. Unlike some states (e.g., Massachusetts, Connecticut), New Jersey does not factor chemical specific background values into their indoor air screening criteria.

While the Department does not subtract background air concentrations from the analytical results, site-specific background sources may be considered when interpreting indoor air data. Background contaminant levels, particularly ambient air results, supercede the Table 1 values when higher since the Department does not require remediation to levels below background concentrations. Background determinations are made on a site-specific basis in consultation with the Department and as part of the overall multiple lines of evidence approach.

9.0 PETROLEUM HYDROCARBONS

9.1 Introduction

As defined in the Underground Storage of Hazardous Substances Rules (N.J.A.C. 7:14 B):

petroleum or petroleum products means all hydrocarbons which are liquid at one atmosphere pressure (760 millimeters or 29.92 inches Hg) and temperatures between -20°F and 120° F (-29° C and 49° C), and all hydrocarbons which are discharged in a liquid state at or nearly at atmospheric pressure at temperatures in excess of 120° F (49° C) including, but not limited to, gasoline, kerosene, fuel oil, oil sludge, oil refuse, oil mixed with other wastes, crude oil, and purified hydrocarbons that have been refined, re-refined, or otherwise processed for the purpose of being burned as a fuel to produce heat or useable energy or which is suitable for use as a motor fuel or lubricant in the operation or maintenance of an engine.

Hydrocarbons as a whole consist of hundreds of chemical compounds that range through volatile, semivolatile, and nonvolatile organic fractions.

Within this document, the Department has indicated a chemical can be considered a source of VI if it has sufficient volatility and toxicity in the subsurface with sufficient mass and/or concentrations to pose a possible inhalation risk within occupied overlying structures. When comparing the two definitions, it is apparent not all petroleum related chemical compounds represent a VI risk. The primary VI risks are associated with the chemical compounds that make up the lighter (shorter carbon chain) petroleum fractions, such as gasoline, diesel fuel, No. 2 heating oil, kerosene and aviation fuel.

The IASL Table (Table 1) lists 52 target volatile organic which are able to be analyzed via USEPA TO-15 method and for which toxicological data exists. Eleven chemicals within this list are routinely associated with one or more of the lighter petroleum fractions discussed above: benzene, toluene, ethylbenzene, xylenes, methyl tertiary butyl ether (MTBE), n-hexane, 1,2,4-

trimethylbenzene, 1,3,5-trimethylbenzene, cyclohexane, 2,2,4-trimethylpentane, and tertiary butyl alcohol.

9.2 Biodegradation

Each of the aforementioned compounds is known to biodegrade under aerobic conditions. Numerous studies have been completed confirming aerobic biodegradation of these chemicals in soil and ground water. However, the rate of attenuation is different for each chemical and, if groups of compounds are present, microbial activity will selectively degrade one chemical ahead of another (e.g., benzene will be preferentially degraded in an aerobic environment ahead of MTBE). The rate of degradation in the vapor phase of each of these chemicals has not been quantified.

At the time this document was prepared, limited studies have been presented to support a biodegradation factor for these chemicals under aerobic conditions. However, as indicated in Section 4.2, Calculation of Ground Water Screening Levels for the Vapor Intrusion Pathway, several resources have suggested values for establishing a degradation factor for benzene, toluene, ethylbenzene, and xylenes ranging from 1 to 35,000. Until additional data is generated, the Department has selected an additional attenuation factor for benzene, toluene, ethylbenzene, and xylenes of 10 times the ground water to indoor air value calculated using the J&E model. Use of the additional attenuation factor assumes a minimum of 4% oxygen exists in the soil column beneath the structure. A biodegradation factor for MTBE, n-hexane, 1,2,4-trimethylbenzene, 1,3,5-trimethylbenzene, cyclohexane, 2,2,4-trimethylpentane, and tertiary butyl alcohol has not been included due to uncertainty over the rate of attenuation in the vapor phase.

As noted in Section 6.1 and consistent with USEPA, the VI pathway warrants investigation when a structure is "located within 100 feet laterally or vertically of a known or interpolated soil gas or ground water contaminants...and the contamination occurs in the unsaturated zone and/or the uppermost saturated zone." (USEPA 2002b). The 100-foot horizontal or vertical distance criterion for investigating the VI pathway does not consider the degradability of the petroleum hydrocarbon compounds. As such the Department will utilize a 30-foot horizontal and vertical

distance criterion for all petroleum related contamination provided non-aqueous phase product is not present. When non-aqueous phase petroleum hydrocarbons are present within 100 feet horizontally or vertically of a structure, the VI pathway warrants investigation.

9.3 Site Evaluation

When a petroleum release occurs and a ground water site investigation is triggered, one or more of the aforementioned 11 chemicals or non-aqueous phase hydrocarbons may be present in ground water in excess of the Department's Ground Water Quality Standards. In these circumstances, as the ground water remedial investigation proceeds an evaluation of the VI risk to receptors must proceed concurrently. The Department has established GWSL for the 11 petroleum-related chemicals (Table 1). If NAPL (as defined in N.J.A.C. 7:26E) is located or suspected within 100 feet of a structure or one of the aforementioned petroleum related contaminants is present in the dissolved phase in excess of the GWSL within 30 feet of a structure, an evaluation of the VI pathway is necessary. For active gasoline service stations, if ground water contaminant concentrations exceed the GWSL, the Department recommends the collection of sub-slab soil gas samples where possible in lieu of indoor air samples. If the sub-slab results are in excess of the SGSL, an institutional control may be required at the site until it can be demonstrated the site contaminant concentrations do not represent a VI risk.

10.0 REMEDIAL ACTION

Remedial action techniques need to be considered when it is determined that the VI pathway is complete and may adversely impact human health. The objective of these remedial techniques is to eliminate the pathway between the source (contaminated ground water and/or subsurface soils) and the receptors (building occupants). Ultimately, though, the NJDEP's primary goal is to remediate the source of the vapor contamination (ground water and/or subsurface soil) such that the risk of VI is eliminated.

This section discusses the various remedial actions appropriate for VI and the operations, monitoring and maintenance provisions associated with these remedial actions. Due to the similarities between VI related to volatile organic compounds and radon, many of the remedial actions discussed below originate from guidance documents addressing radon mitigation.

10.1 Remedial Action Techniques

While remedial investigation and remedial action of the vapor source are ongoing, remedial action techniques should be implemented to prevent VI. The NJDEP generally does not review engineering design specifications for VI remedial systems. The investigator or entities responsible for implementing the VI remedial system shall demonstrate the effectiveness of the remedial action by collecting verification samples (see 10.3.2.1). Some remedial action techniques are listed below; the first three of which are typically implemented at a minimum:

- Sealing openings and cracks with caulk or expanding foam (preferably volatile-free)
- Repairing compromised areas of the slab or foundation
- Covering and sealing exposed earth and sump pits
- Installing a sealed vapor barrier (e.g., plastic sheeting, liquid membrane) over earthen, gravel, etc. floors or crawlspaces
- Utilizing natural ventilation
- Installing a subsurface depressurization system
- Installing a pressurized air curtain

- Utilizing house pressurization
- Utilizing heat recovery ventilation
- Installing a soil vapor extraction system

Subsurface depressurization systems are the most common remedial action technique and as such are discussed in detail below.

10.1.1 Subsurface Depressurization Systems:

There are various types of subsurface depressurization systems as discussed below and in more detail in the USEPA's Radon Reduction Techniques for Existing Detached Houses - Technical Guidance (USEPA 1993). The objective of the subsurface depressurization system is to apply a negative pressure field or vacuum beneath and/or around the building of concern, thereby preventing VI into the building. Subsurface depressurization systems can be either passive or active, however NJDEP only accepts active systems for remediating VI in existing buildings (see Section 10.2.4 for pre-construction options). Active subsurface depressurization systems utilize a fan to create the negative pressure field (vacuum).

1. Sub-Slab Depressurization can be used when a building has a slab (e.g., concrete) floor. Piping is installed in the subsurface beneath the slab and a fan is used to create a negative pressure field in the sub-slab area and discharge any vapor outside the building. Depending on the size of the slab and the characteristics of the sub-slab material, piping may have to be installed beneath the slab in multiple locations in order to create a negative pressure field across the entire sub-slab area. Piping configurations depend on the construction and design of the building of concern however piping is typically inserted vertically through the existing slab. In a new construction scenario, lateral perforated piping can be installed prior to installation of the slab. See Figure 10-2 for more details.
2. Sub-Membrane Depressurization can be used when a building has an earthen (or gravel, etc.) floor or crawlspace, as opposed to a slab. A membrane such as plastic sheeting is

used to cover the earthen floor or crawlspace area and, similar to Sub-Slab Depressurization, a negative pressure field is created beneath the membrane thereby preventing VI across the membrane. The membrane needs to be properly sealed to the building walls, etc. and kept intact in order to maintain the negative pressure field. The piping that is used to create the negative pressure field beneath the membrane can be configured in various ways. Piping can be inserted vertically through the membrane in multiple locations or perforated piping can be laid horizontally beneath the membrane. See Figure 10-3 for more details.

3. Block-Wall Depressurization can be utilized when a building has a block wall foundation. In this scenario the negative pressure field is created via piping inserted through the voids in the block wall. Any openings in the top of the block wall and all openings or cracks on the interior surface of the wall should be sealed. This technique is typically used in conjunction with one of the other depressurization techniques. See Figure 10-4 for more details.
4. Drain Tile Depressurization can be utilized when a building has a loop of perforated drain tiles (piping) adjacent to the building footers for water drainage. If the drain tiles discharge to a sump pit, the sump pit is sealed and the negative pressure field is applied to the sump pit. If the drain tiles discharge to an outdoor location the negative pressure field is applied to the drain tile loop at an outdoor location. See Figure 10-5 for more details.

10.2 Remedial Action Implementation

10.2.1 Remedial Action System Requirements

Subsurface Depressurization System requirements in USEPA's Radon Mitigation Standards (USEPA 1994), <http://www.epa.gov/radon/pubs/mitstds.html>) detail system design, installation and evaluation guidance. As detailed in USEPA Radon Guidance, the subsurface depressurization system should be designed to prevent backdrafting of combustion products into a structure. Additionally, as a safety precaution, the depressurization system fan should be

located outside of the building as the fan housing is the most likely location for a leak to occur in the system. NJDEP recommends subsurface depressurization systems contain the following:

- A pressure gauge (u-tube manometer) for determining operational efficiency;
- An alarm that informs building occupants in case the system malfunctions;
- Labeling that indicates the purpose of the system along with the name, address and telephone number of the entity to contact for questions, repairs, etc.

10.2.2 Qualifications

NJDEP recommends that a New Jersey Certified Radon Mitigation Business (<http://www.nj.gov/dep/rpp/radon/certmit2.htm>) or licensed Professional Engineer be consulted for the design, installation, monitoring and maintenance of vapor remediation systems. The proposed vapor remediation system shall be certified (by the aforementioned persons or firms) as being effective for addressing VI.

10.2.3 Permits

Permits (e.g., Air Pollution Control, Electrical, Plumbing) shall be obtained from the appropriate regulatory authority, as necessary, prior to installation of the remediation system.

An air permit is required from NJDEP for subsurface depressurization systems installed in certain buildings. One or two family dwellings and a dwelling of six or less family units, one of which is owner occupied, are exempt from obtaining an Air Pollution Control Permit and Certificate pursuant to N.J.S.A. 26:2C-9.2.d. An Air Pollution Control Permit and Certificate however is required at other locations (e.g., large apartment buildings, retail and industrial establishments) pursuant to N.J.A.C. 7:27-8.2(c)16. For further details, contact the appropriate regional NJDEP Air Enforcement Regional Office (<http://www.nj.gov/dep/enforcement/air.html> or 609-633-7994) to determine if your system requires an Air Pollution Control Permit and Certificate.

NJDEP Air Enforcement staff are located at four regional offices throughout the state of New Jersey as follows:

Metro Region

(973) 656-4444

Jurisdiction: Bergen, Essex, Hudson Counties

Northern Region

(973) 656-4480

Jurisdiction: Hunterdon, Morris, Passaic, Somerset, Sussex, Warren Counties

Central Region

(609) 584-4100

Jurisdiction: Mercer, Middlesex, Monmouth, Ocean, Union Counties

Southern Region

(856) 614-3601

Jurisdiction: Atlantic, Burlington, Camden, Cape May, Cumberland, Gloucester, Salem Counties

10.2.4 Pre-Construction Considerations

As previously stated, the NJDEP's primary goal is to remediate the source of the vapor contamination (ground water and/or subsurface soil) such that the risk of VI is eliminated. However, it is often not technically possible or feasible to complete such remediation in a timely manner. Therefore, if a property designated for development has a potential for vapor intrusion risk, the Department recommends that proactive measures (vapor barrier, vapor barrier with passive depressurization system, active depressurization system, etc.) be designed into the building. These proactive measures are relatively inexpensive, especially compared to the cost of retrofitting them after the building is constructed.

For planned building construction projects (e.g., Brownfield Redevelopment Sites), USEPA's Building Radon Out: A Step-by-Step Guide on how to build Radon-Resistant Homes (USEPA 2001d) provides technical guidance on preventative measures that should be considered prior to building construction. This document is available on the Internet at <http://www.epa.gov/iaq/radon/images/buildradonout.pdf>.

Additionally, New Jersey Department of Community Affairs (N.J.A.C. 5:23-10.1 et seq.) requires particular building specifications for new homes built in Tier 1 radon areas (<http://www.nj.gov/dep/rpp/radon/radonin.htm>). These requirements include constructing the building with a layer of gravel and a vapor barrier under the foundation, installing piping for a mitigation system, sealing all openings with a non-cracking polyurethane caulk and installing a

roughout for an electrical junction box. Also, if the foundation walls are made of cinder block or other hollow masonry, the tops of the foundation walls should be capped or the voids of the blocks should be completely filled.

10.3 Remedial Action Operation, Monitoring and Maintenance

A Remedial Action Workplan (RAW) that addresses the items below shall be submitted to NJDEP in accordance with N.J.A.C. 7:26E.

10.3.1 Institutional and Engineering Controls

The investigator shall consult the Technical Requirements for Site Remediation (N.J.A.C. 7:26E-8) for detailed institutional and engineering control requirements, if appropriate.

Remedial actions (or interim remedial measures) that involve the installation of subsurface systems, vapor barriers, or other similar devices or engineering controls (including but not limited to those actions discussed in Section 10.1) do not require an institutional control, provided official notification of the property owner/occupant is provided (see Section 7.9). The responsible party, however, is accountable for the system verification sampling, monitoring and maintenance requirements noted in Section 10.3.2, below.

For undeveloped properties/parcels that contain source concentrations above the generic screening levels (GWSL or SGSL), official notification of the property owner is necessary. Institutional controls will be required upon request for closure by the responsible party.

The option to use the nonresidential screening levels (SGSL, IASL, or OSHA values where appropriate) is contingent upon the responsible party obtaining an agreement with the property owner and the implementation of an institutional control at the affected structure/property. The agreement should be submitted as part of the RAW. This provision is necessary to address future modifications in the land use (e.g., conversions to residential use).

Likewise, the option to use site-specific building parameters (e.g., ventilation rate changes, building size modifications, positive pressure controls) would necessitate an agreement with the property owner and the implementation of an institutional control at the affected structure/property. Utilization of the GWSL for Alternate Soil Textures does NOT require an institutional control.

Depending on the type of institutional control employed, the responsible party may have to monitor change in ownership and building conditions every six months and inform the NJDEP of these observations periodically through RA Progress Reports, biennial certification, or other appropriate mechanisms. This is critical in situations where nonresidential screening levels or site-specific building parameters are utilized.

10.3.2 Remedial Action System Verification Sampling, Monitoring and Maintenance

10.3.2.1 *Verification Procedures*

After the remedial system is operational, confirmation indoor air sampling should be conducted. Indoor air sampling should be conducted approximately two to four weeks after the remedial system is operational to verify the effectiveness of the system. Indoor air sampling events that do not occur during the winter or early spring (November through March) should necessitate a second round of indoor air sampling during this timeframe. However, the Department will accept a single round of sampling (irrespective of the seasonal timing of the sample event) in those cases where the results are an order of magnitude below the appropriate screening level.

If the indoor sampling data for the contaminants of concern are above the NJDEP's IASL (with consideration of background sources), modifications or supplementation to the existing remedial action system will be required. Additional indoor air sampling will be necessary to verify the effectiveness of the remedial system if it has been modified. Once indoor air data collected during the winter or early spring are below the NJDEP's IASL (or site-specific background concentrations), additional indoor air sampling may not be necessary until system termination sampling takes place.

If subsurface depressurization systems are the chosen remedial system, in addition to indoor air sampling, it should be demonstrated, immediately after system startup, that a negative pressure field exists beneath the building, or appropriate portion of the building, of concern. This information should be collected by an entity with the qualifications detailed in section 10.2.2 and submitted with the verification indoor air sampling results. These diagnostic provisions should be incorporated into the original design of the subsurface depressurization system to avoid modifications to the remedial system after installation. Additional information on diagnostic testing can be found in the State of Massachusetts Guidelines for the Design, Installation, and Operation of Sub-Slab Depressurization Systems (MassDEP 1995).

10.3.2.2 Monitoring and Maintenance

A monitoring and maintenance plan shall be submitted for NJDEP review and approval. For subsurface depressurization systems, the pressure gauge (typically a U-tube manometer) should be monitored quarterly to determine if the system is operating efficiently. A reduced monitoring frequency may be appropriate after one year of successful operation of the remedial system. If the pressure gauge indicates the system is not operating efficiently the system should be diagnosed and repaired. The pressure gauge measurements should be recorded over time in tabular format and updated with each submittal to NJDEP.

An inspection should be conducted semiannually to determine if any new or existing areas (e.g., cracks, holes, sump pit covers, earthen crawlspaces) need to be sealed, caulked, and/or covered, etc. If repairs are necessary they should be conducted and documented in the next submission to NJDEP. A reduced inspection frequency may be appropriate after one year of efficient operation of the remedial system.

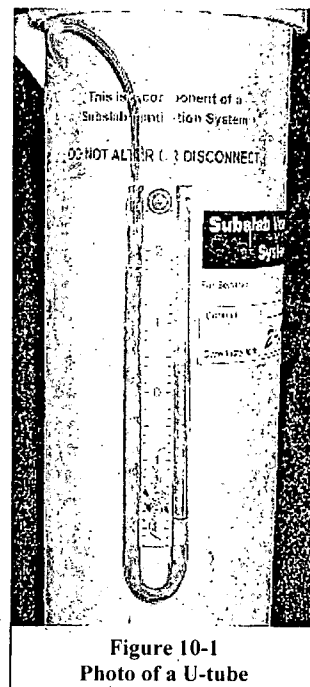


Figure 10-1
Photo of a U-tube

10.3.2.3 Remedial Action Progress Report Submission

Remedial Action Progress Reports shall be submitted in accordance with The Technical Requirements for Site Remediation (N.J.A.C. 7:26E).

10.3.2.4 System Termination Sampling

Once the investigator concludes that the VI source (ground water, soil gas, etc.) has been properly remediated to the point where the VI pathway is not complete, a proposal may be submitted to NJDEP to cease operation of the VI remedial system. Upon approval from NJDEP, system termination sampling of indoor air and sub-slab soil gas should be collected. The system termination sampling should occur during the winter and early spring (November through March). Sampling should be conducted as outlined in Section 6.4 (Sub-Slab Soil Gas Sampling Procedures) and Section 6.6 (Indoor Air Sampling Procedures). The system termination indoor air and sub-slab analytical results should be submitted in a Remedial Action Progress Report for NJDEP review. Note subsequent sampling rounds may be required on a case by case basis to verify the appropriateness of system termination. Analytical parameters for the system termination samples should include the contaminants of concern analyzed after the initial startup of the remedial system. However, additional analytical parameters may be required on a case by case basis.

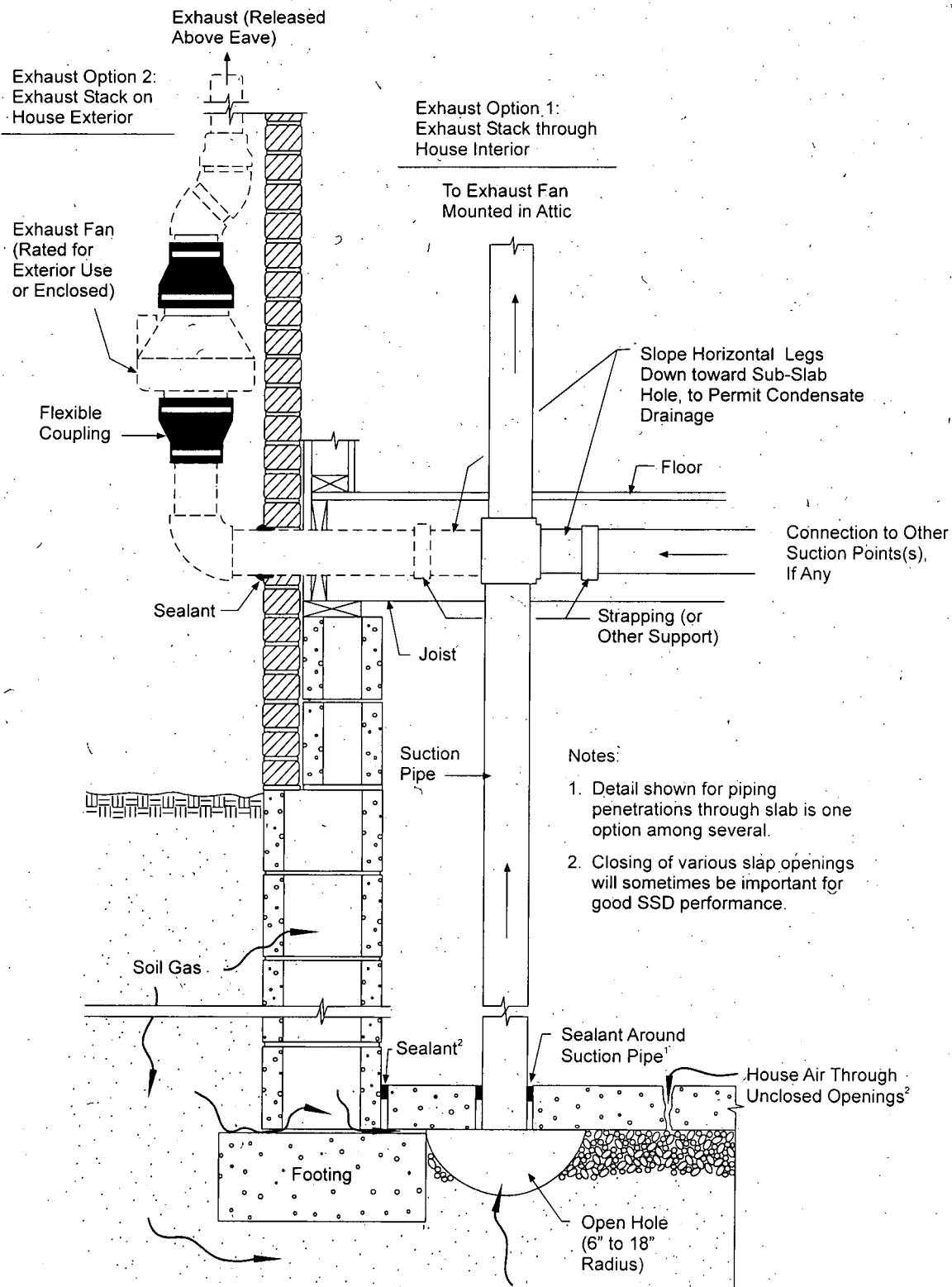


Figure 10-2: Example of a Sub-Slab Depressurization System

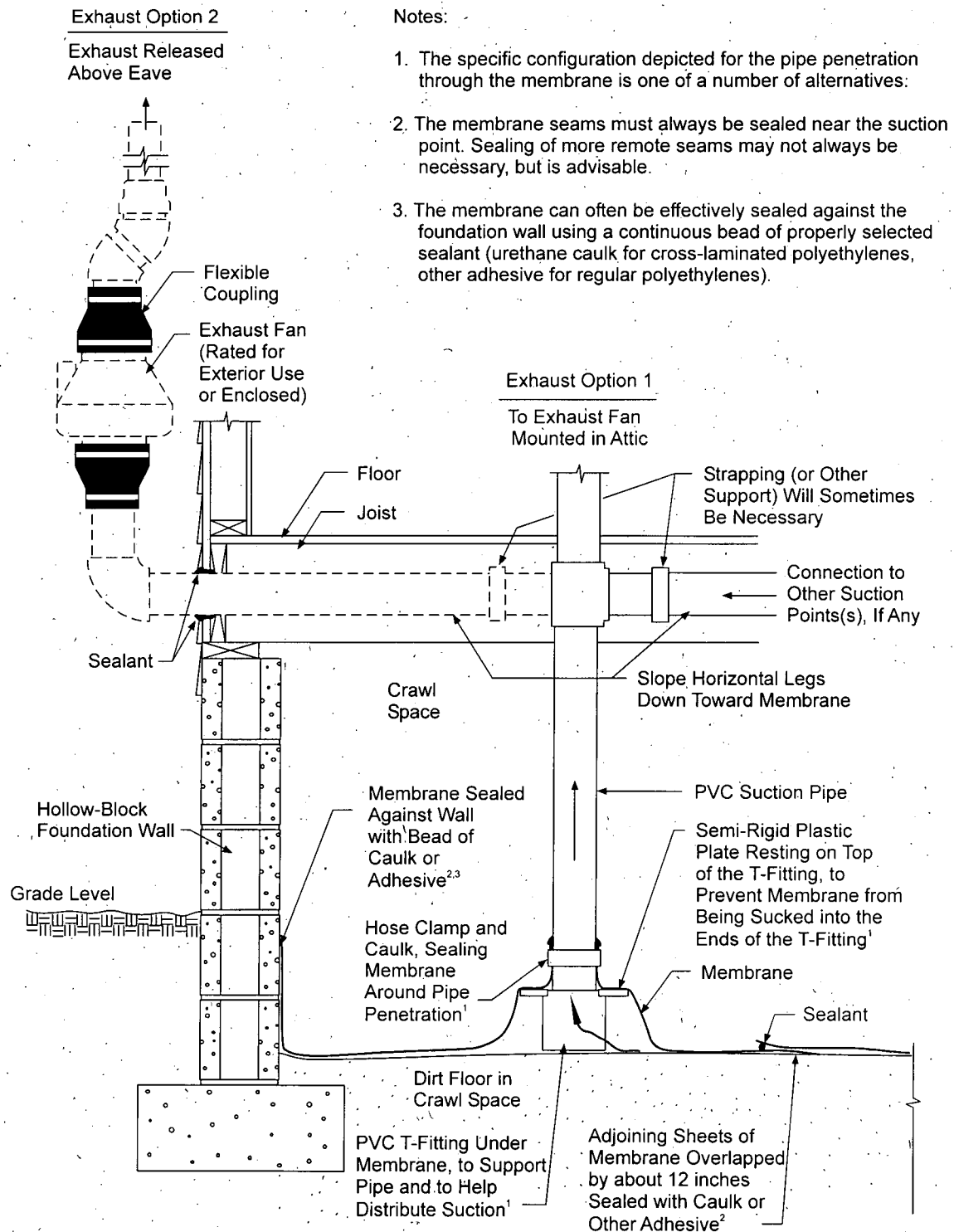


Figure 10-3: Example of a Sub-Membrane Depressurization System

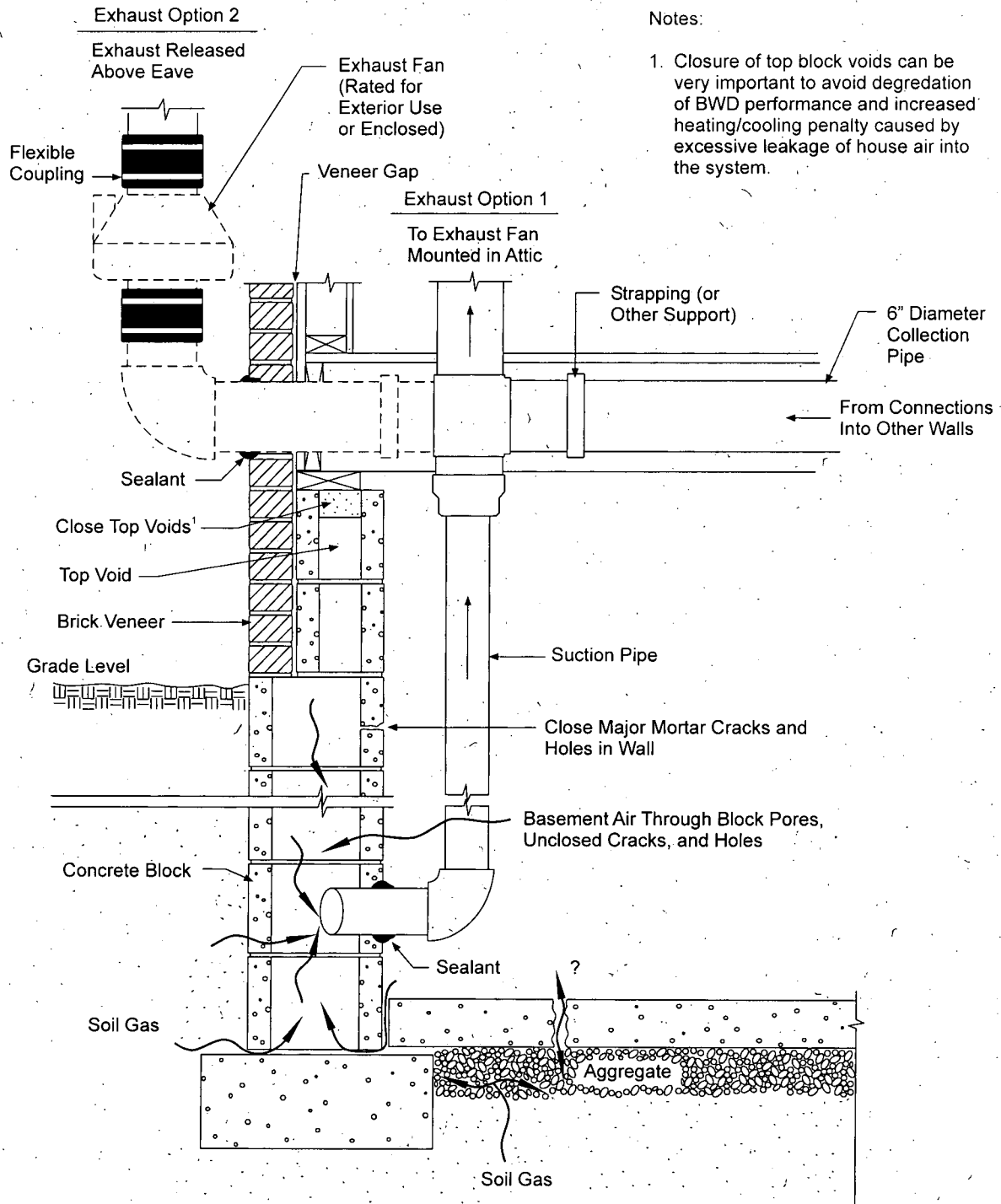
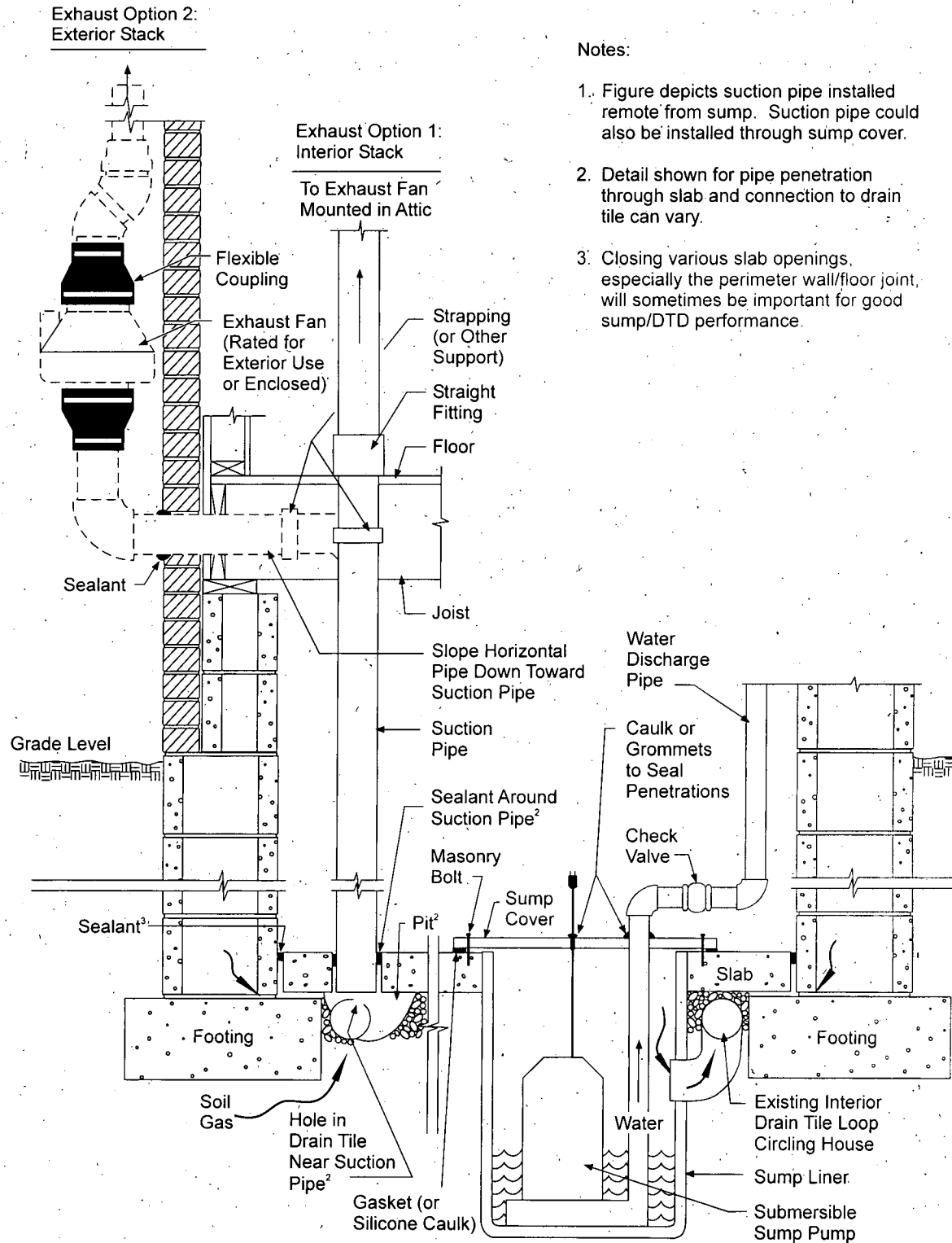


Figure 10-4: Example of a Block-Wall Depressurization System



Notes:

1. Figure depicts suction pipe installed remote from sump. Suction pipe could also be installed through sump cover.
2. Detail shown for pipe penetration through slab and connection to drain tile can vary.
3. Closing various slab openings, especially the perimeter wall/floor joint, will sometimes be important for good sump/DTD performance.

Figure 10-5: Example of Drain-Tile Depressurization System

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